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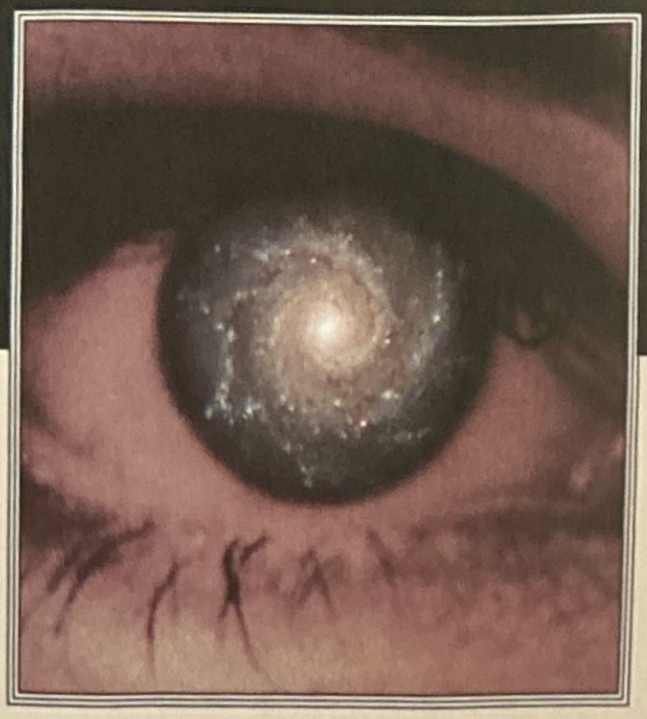
OUR UNDISCOVERED UNIVERSE



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There is a very simple reason for this catastrophic, intractable mess. Theorists stopped asking *why* a long time ago. Without the *why*, the search for mathematical symmetries becomes numerology, not science. No telescope or particle accelerator, regardless of its size, is going to tell us *why* the universe is the way it is. When the *why*'s remain unanswered, there is no understanding. When there is no understanding, there is no progress. But this sad situation is about to change forever.

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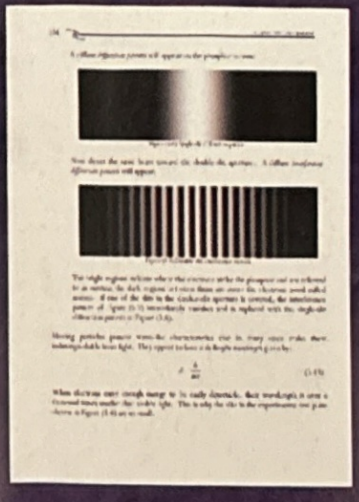

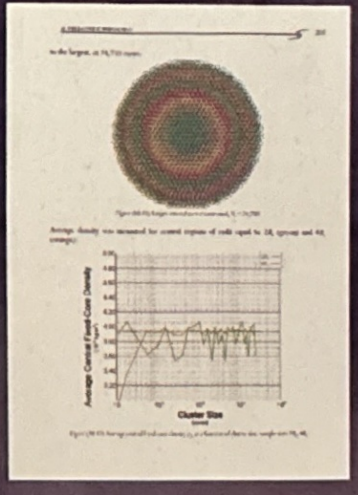

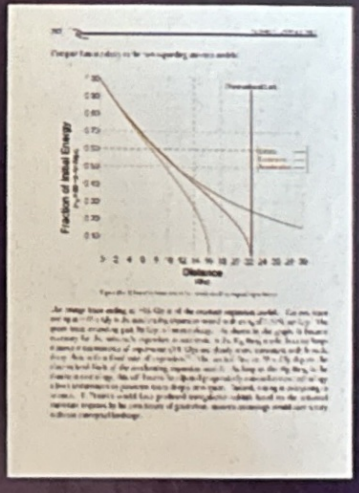

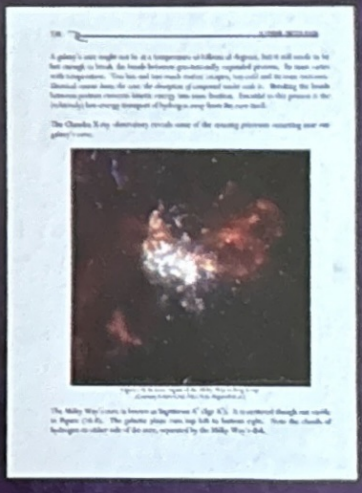

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Human limb regeneration may be on the horizon, thanks to a discovery in mice.

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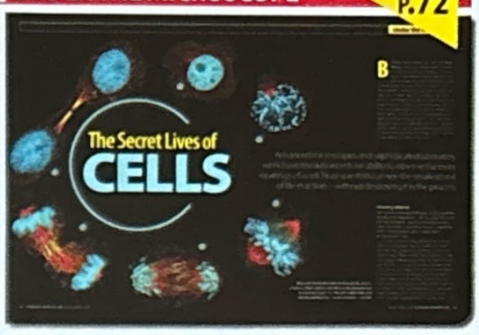

We can now see the smallest units of life in action without destroying them in the process.

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At Borneo's "orangutan school," rescued great apes learn how to survive in the wild.

"A young orangutan that has grown up as a pet in a wealthy home has no ability to fend for itself in the wild."

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New methods for dating an ancient volcanic eruption are forcing experts to rewrite history.

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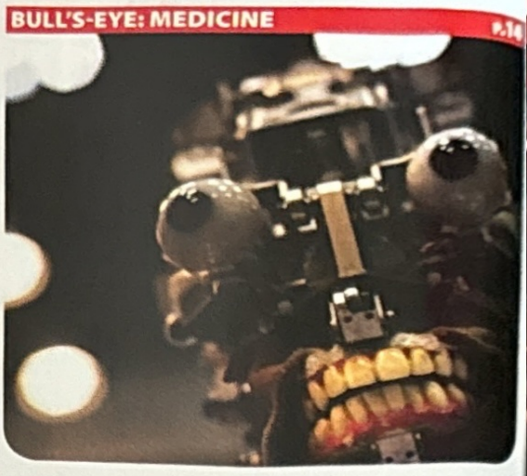
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Finding the first perfect number, the iceberg that nearly reached the tropics, and other unlikely nuggets of scientific knowledge.

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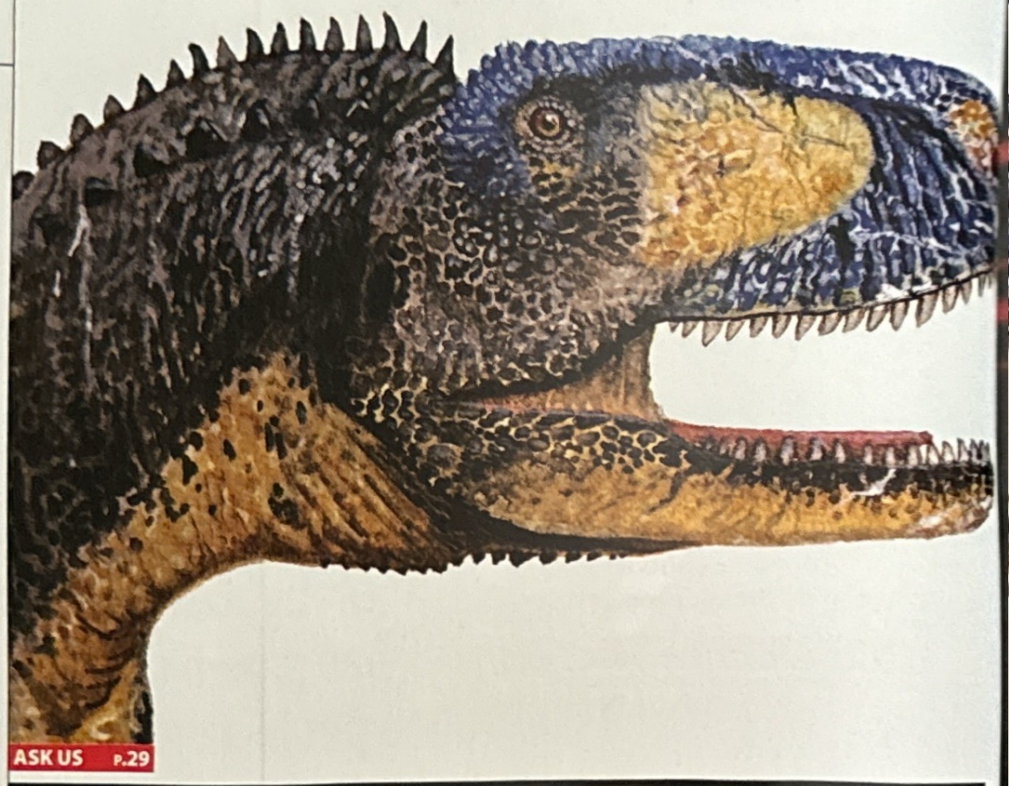
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Praise For Our Premiere Issue

I just wanted to say: What an exciting first issue of a magazine. I've tried reading many science magazines and was either bored out of my mind or couldn't understand half of it. But everything in this one is worth reading!

Darlene Swords via e-mail

I just received your Jan./Feb. issue, and I couldn't put it down. This is one of the first magazines that I found to be intellectually stimulating not only to me, but to my family as well. The format and pictures made it easy for my seven-year-old daughter to follow and kept her interested. Thank you for making a magazine that isn't too difficult for younger people to read.

Gayle Frage via e-mail

I've been waiting for more than 20 years for a science magazine like this to come along! SCIENCE ILLUSTRATED is full of knowledge for people from all walks of life. I hope it lasts for years.

Gary Truax via e-mail

I'm so impressed! Scientists may have different interpretations of events than Christians have, but the pictures in your first issue gathered in the name of science show God's glory all the same.

Anne Weddle via e-mail

Evolution Eruption

I noticed that the "explosion of creativity" described in "The Great Migration" was roughly contemporaneous with the Toba volcanic supereruption around 75,000 years ago. That event reduced the early human population around the world to as few as 5,000 to 20,000, killing off all but those who became Neanderthals and those who are the ancestors of modern humans.

John Hord via e-mail

[**Ed:** A fair point. But it's important to note that volcanic eruptions that far back are difficult to date accurately, as you'll read in this issue's story about the explosion of Santorini, on page 46.]

Correction

On pages 75 and 77, *Bitis gabonicus* is identified correctly in Latin, but incorrectly in English. It is actually a Gaboon viper, not a puff adder. Puff adders are a close relation.

Peter Kruger via e-mail

[**Ed:** Thank you for bringing this to our attention. The snakes pictured on pages 75 and 77 are in fact Gaboon vipers.]

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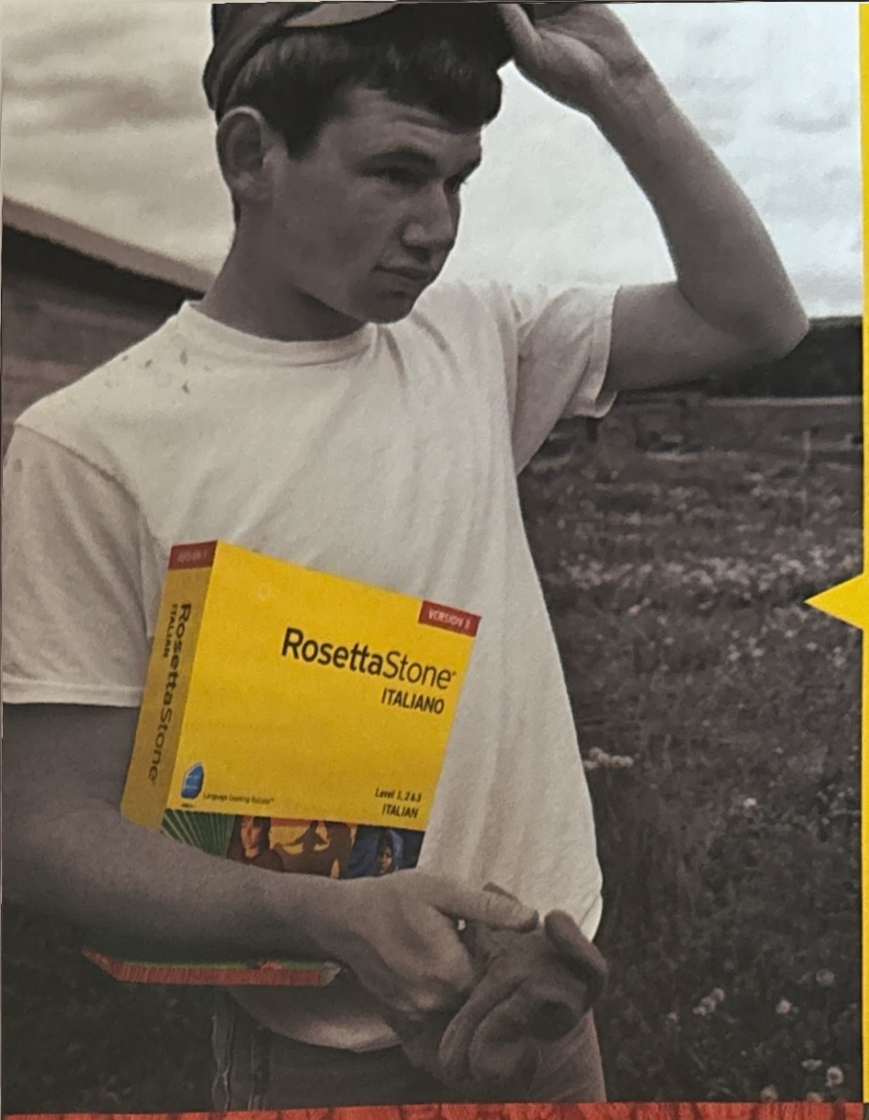

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Sweet Sacrifice

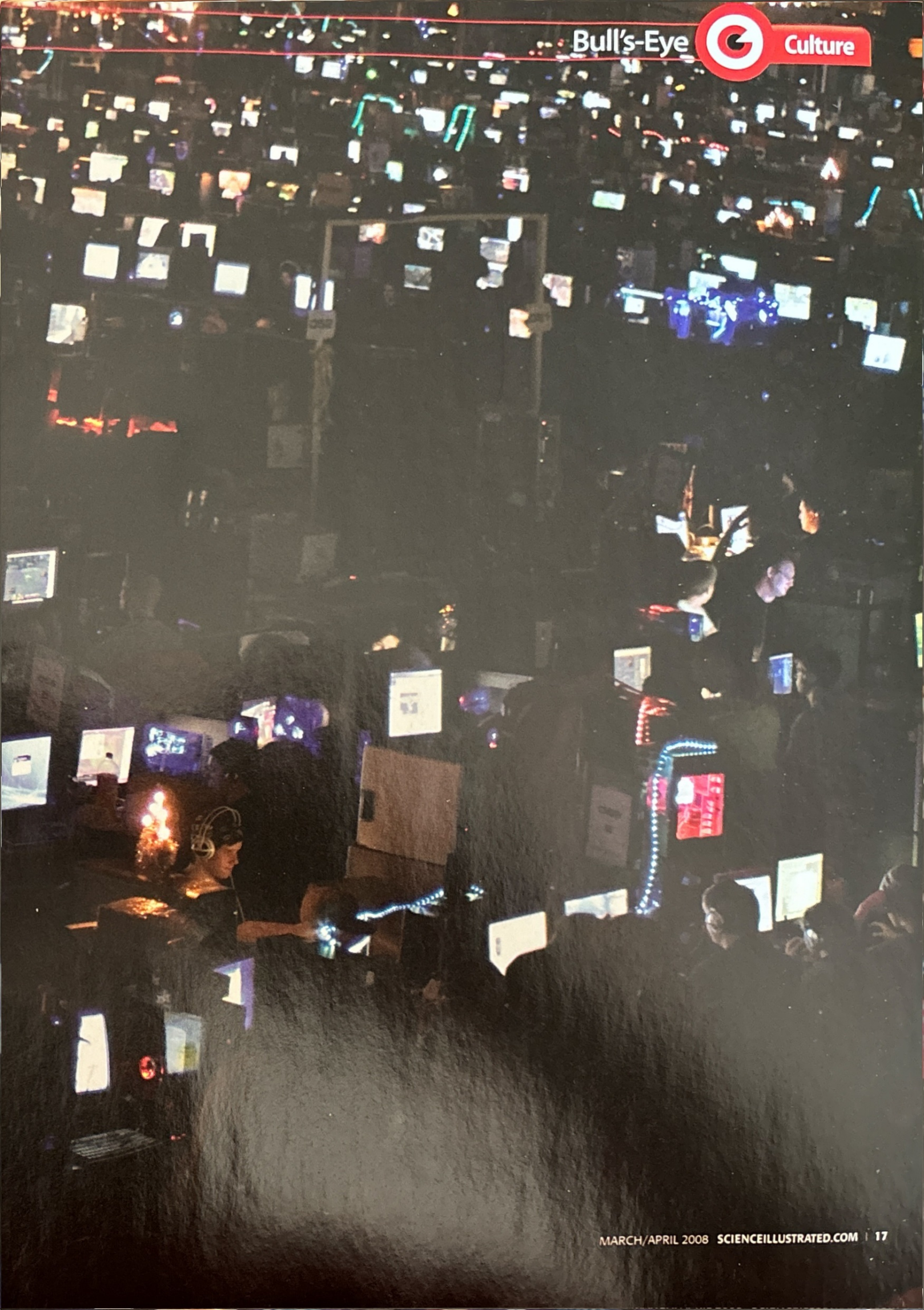
Talk about taking one for the team: To feed their fellow colonists during the dry season—when food is sparse—certain honey ants, known as "repletes," of the American West, Mexico and Australia act as nectar-storage vessels. The volunteers, which are generally the larger members, permanently attach themselves to the hive and wait for honey to be delivered via the mouths of their more mobile peers. Repletes then gorge themselves on the sweet stuff, filling themselves until their abdomen reach the size of a small grape. When hunger threatens the colony, the swollen repletes become stimulated and then regurgitate the nourishing nectar.

Better It Than You

Meet Simroid, the latest in anthropomorphic training tools. Equipped with a mouth full of feedback sensors, this robot senses dental-student missteps and reacts in a decidedly unrobotic way: grimacing, blinking nervously, and yelping in pain. A gag-reflex sensor makes her alert students if tools slip too far back in the mouth. A hit at Tokyo's 2007 International Robot Exhibition, where it was presented by Japanese robotics firm Kokoro, the android won over onlookers with its liveliness. Human-like skin, air-powered muscles and detailed facial expressions all contributed to the effect. The creators hope the 'bot will soon be used in classrooms to teach not just dentistry but also empathy for patients, be they flesh or steel.

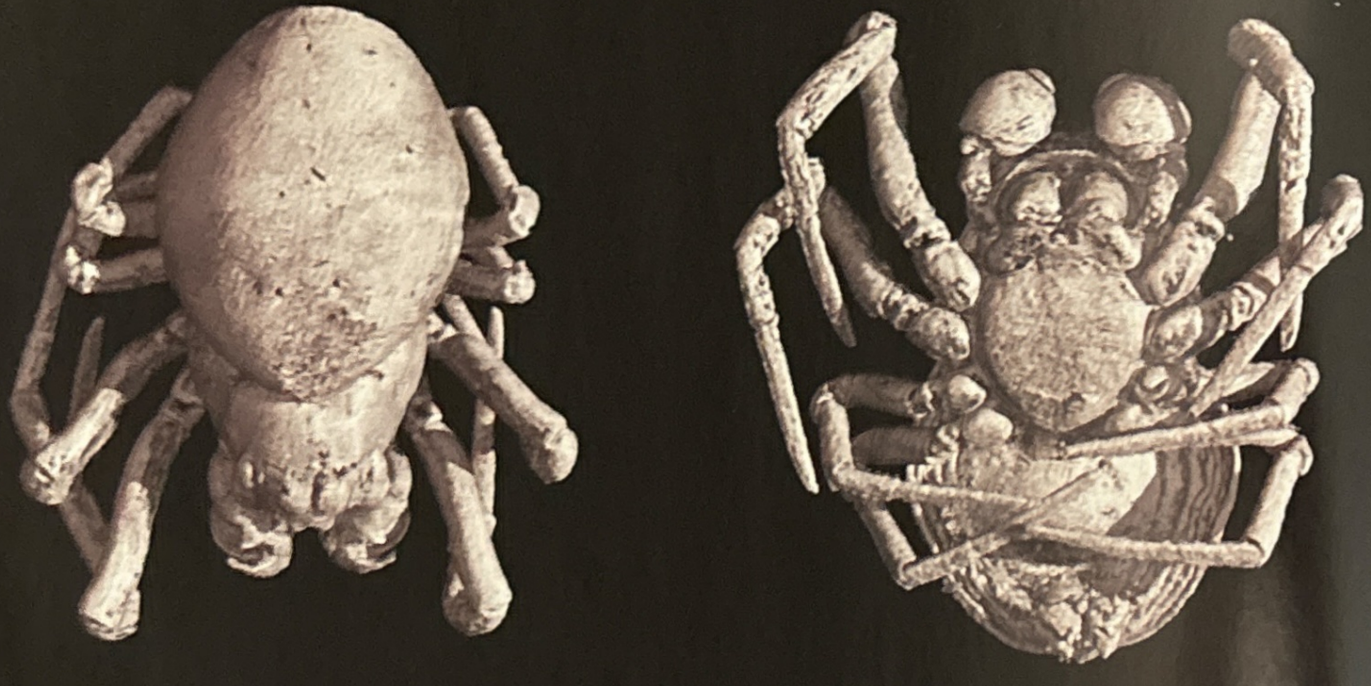
Extreme Networking

Thousands of computer enthusiasts gather in Jönköping, Sweden, twice a year to plug their computers into a single local-area network, thus forming a massive "LAN party." The most recent event, DreamHack Winter 2007, ran continuously from 8 a.m. on November 29 through noon on December 2. It featured gaming competitions, product demos, live music and more. Over 13,000 participants plugged 10,445 computers into the Elmia Exhibition Centre's local-area data network—potentially setting the Guinness world record for the biggest LAN party in history. Sleeping areas were provided for the weary, and energy drinks for the ambitious. Meanwhile, a cooling system used water from nearby Lake Vättern to counteract the heat generated by the computers: an output of some three million watts from one very powerful network.



X-Ray Advancement

This 53-million-year-old spider was dissected without slicing into the amber in which it's suspended. Using technology previously reserved for medical purposes, David Penney, a paleo-arachnologist at the University of Manchester, was able to study the one-millimeter-long arachnid in minute detail. Penney's colleagues at Ghent University in Belgium improved upon very-high resolution x-ray computed tomography (VHR-CT), which allows specimens to be sliced by x-rays rather than scalpels. The technique renders 3–D reconstructions that can be examined from any angle to reveal the *Cenotextricella simoni*'s internal organs, without damaging the fossil.



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Science Update

IN BRIEF In Queensland, Australia, researchers found fossils of **20 previously unknown species** that flourished from 10 million to 20 million years ago. Among the discoveries at the site: a carnivorous kangaroo, a tree-climbing crocodile, and a large, flesh-eating bird.

Earthquake Lubricant

GEOLOGY Two miles beneath the famous San Andreas Fault in California, geologists have made a surprising discovery. Numerous veins of soft talc run through masses of hard rock and reduce the severity of earthquakes.

The talc allows the overlying rock layers to glide quietly and easily by each other. But where there is no talc buffer, the rock layers collide and sometimes shift suddenly, creating violent earthquakes.

Geologists have found talc along a 30-mile stretch of the San Andreas Fault.

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Outer-Space H_2O

A discovery may reveal how water finds its way to the planets

Scientists have detected traces of water vapor around star IRAS 4B.

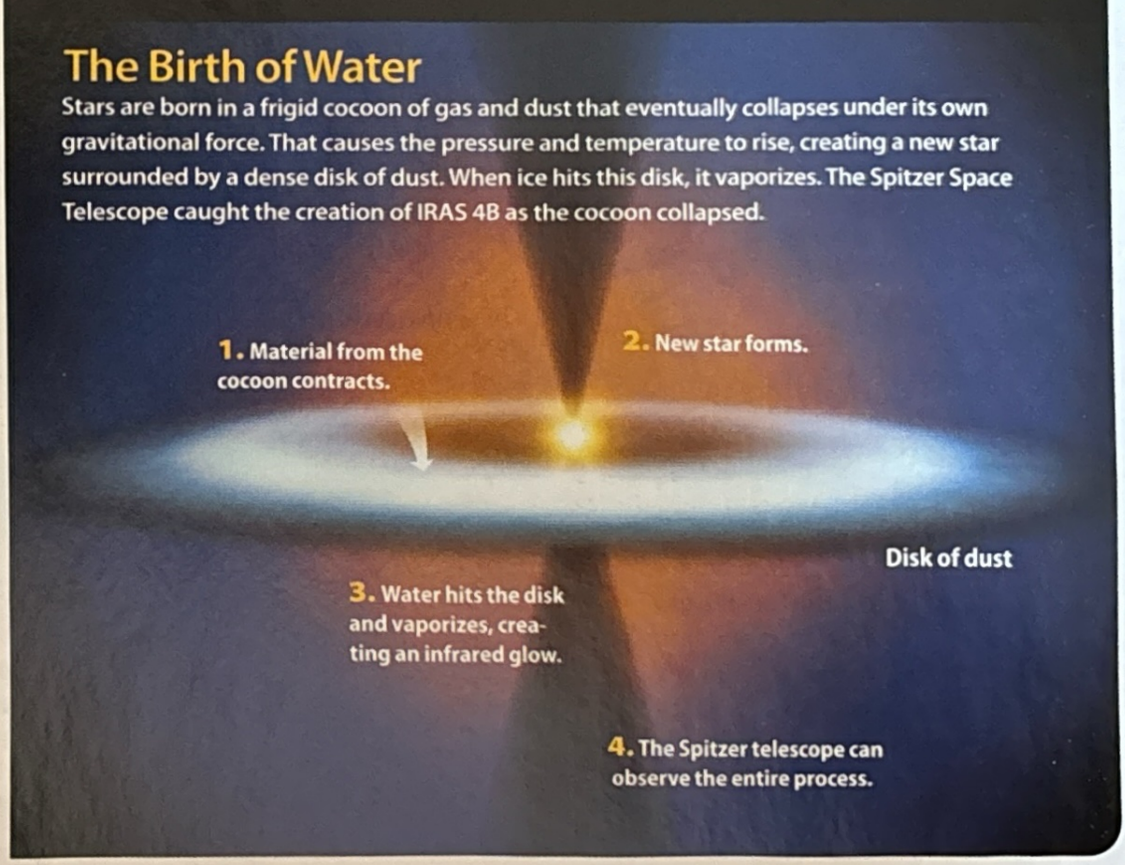
ASTRONOMY Thanks to a star system that lies 1,000 light-years from Earth, astronomers have seen for the first time how water gets to regions where new planets are born.

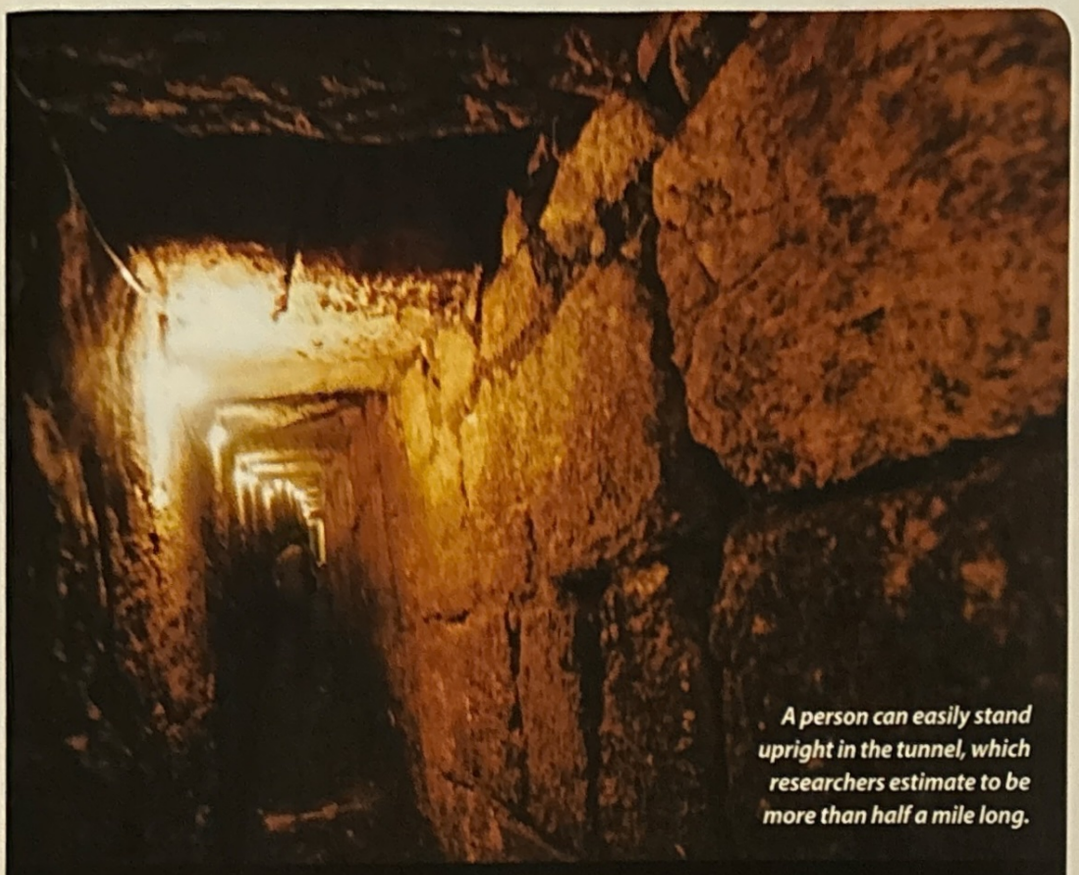
Using the infrared Spitzer Space Telescope, NASA astronomers studied the early star IRAS 4B in the NGC 1333 nebula, which is part of the constellation Perseus. A huge cloud surrounds the star system, and ice "rains" down from it on a warm disk of dust where planets may form. The disk surrounds a newly created star that is still absorbing surrounding material.

When the ice hits the disk, it becomes steam and then freezes again, turning into asteroids and comets that could ultimately carry water to new planets. It is thought that water was originally brought to Earth in this way. According to NASA, the telescope has detected enough water around the star to fill the Earth's oceans five times over.

The Birth of Water

Stars are born in a frigid cocoon of gas and dust that eventually collapses under its own gravitational force. That causes the pressure and temperature to rise, creating a new star surrounded by a dense disk of dust. When ice hits this disk, it vaporizes. The Spitzer Space Telescope caught the creation of IRAS 4B as the cocoon collapsed.


1. Material from the cocoon contracts.
2. New star forms.
Disk of dust
3. Water hits the disk and vaporizes, creating an infrared glow.
4. The Spitzer telescope can observe the entire process.



A person can easily stand upright in the tunnel, which researchers estimate to be more than half a mile long.

Ancient Escape Route Discovered under Jerusalem

When the Romans conquered the city in A.D. 70, its inhabitants fled through a drain tunnel

ARCHAEOLOGY Fortunately, archaeologists don't always find what they're looking for. Researchers in Jerusalem hunting for an ancient avenue stumbled upon an even greater discovery: a tunnel dating to the beginning of the first millennium. The tunnel was intended as a drain, but in A.D. 70, the city's inhabitants used it to flee the burning city as the Roman Emperor Titus and his army reduced most of the city to ruins.

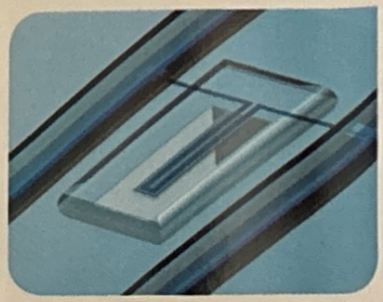
The well-preserved tunnel is built of massive stone slabs that measure more than three feet deep and are as high as 10 feet. Archaeologists have found numerous artifacts inside, including coins and pottery fragments that date to the time of the Roman siege. Jerusalem's population numbered in the tens of thousands; to avoid either slaughter or slavery, many of the people sought refuge in the tunnel.

Most of Jerusalem was left in ruins when the city was sacked by the Romans in A.D. 70.

Scales Can Weigh a Living Cell

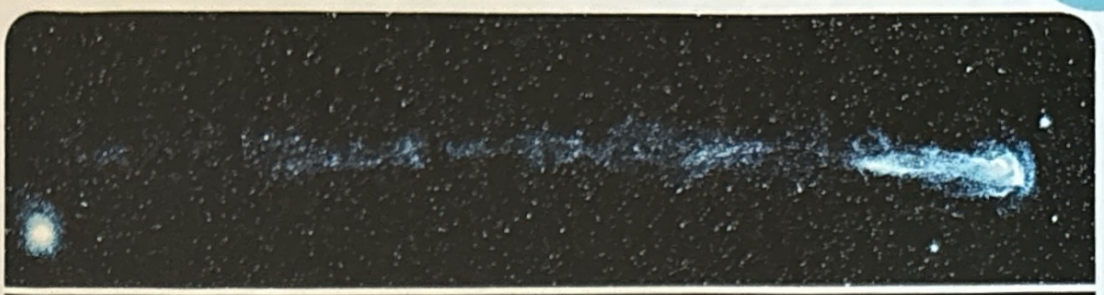
TECHNOLOGY Scales that measure the world's tiniest particles work by using a nanoscopic, diving-board-like cantilever that bounces. By measuring the frequency at which the board vibrates, researchers can determine the particle's weight. Such scales have, until now, suffered from a serious limitation when measuring cells in liquid because the scales' vibrations were altered when surrounded by fluid. Researchers at the Massachusetts Institute of Technology solved that problem by running the fluid through tiny channels on the cantilever rather than immersing the entire cantilever in the fluid.

One potential use for the nanoscales is to make an inexpensive sensor to detect certain disease-causing bacteria or specific cells in a blood sample. The number of CD-4 cells in the blood of an AIDS patient, for example, reveals the condition of the patient's immune system. So far, researchers have been able to weigh a single bacterium with a weight of 110 femtograms. (One femtogram is a millionth of a billionth of a gram.)



New nanoscales can weigh cells in liquids—for example, CD-4 cells in the blood of AIDS patients.

CLOCKWISE FROM TOP: NASA/JPL-CALTECH; UNIVERSITY OF KWAZULU-NATAL; CONSERVATION LEADERSHIP PROGRAM



It's a Comet! It's a Star! It's a Comet-Star!

An ultraviolet telescope finds an unusually fast-moving star trailing a gas tail

The star Mira [extreme right] has a 13-light-year-long gas tail. Mira is moving so fast that heat generated by its shock wave leaves a kind of cosmic wake behind it.

ASTRONOMY NASA's Galaxy Evolution Explorer ultraviolet telescope has discovered a star that is rushing through the Milky Way trailing a 13-light-year-long gaseous tail in its wake. Until now, this phenomenon had never been seen in a star.

The star itself, Mira, is well known, but this telescope—GALEX, for short—spotted the tail, which is visible only in the ultraviolet spectrum, in 2007. The tail consists of carbon, oxygen and other elements that Mira has shed over the past 30,000 years. It is moving at 291,000 mph, far faster than the stars around it, and has a bow shock in front of it, a build up of gas similar to the buildup of water in front of a speedboat. As this heated gas falls behind the star, it hits cooler gases, emitting ultraviolet radiation, which GALEX is able to detect.

IN BRIEF Researchers from Yeshiva University in New York City have discovered that **some fungi can use radiation in a manner similar to that of photosynthesis**, in which green plants convert sunlight into energy. The more radiation the fungi take in, the bigger and stronger they become.

21,342

people were killed in natural disasters in 2006, according to the World Health Organization, and 134.6 million suffered injuries or loss of property.

New Species Alert

A team of biologists has discovered a new species of frog in a remote mountainous region in Colombia. The "golden frog of Supatá" is less than an inch long, and found only within a particular 50-acre area—likely the reason the frog had previously eluded scientists. Toxic to most of its predators, it is one of the so-called poison-dart frogs.

Was this 140-million-year-old dinosaur an ancestor of birds?

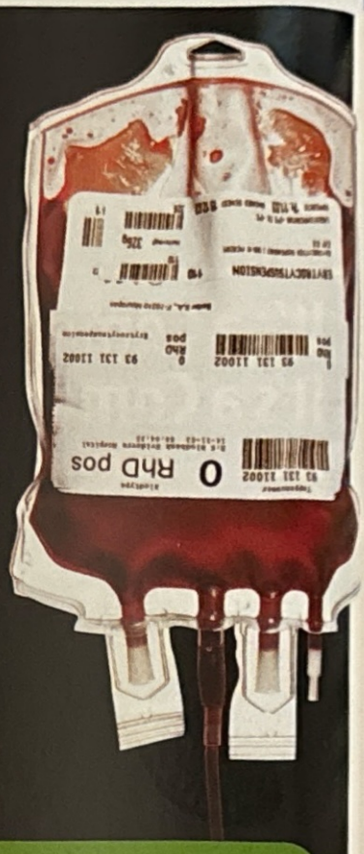
Researchers Pluck "Feathered Dinosaur" Theory

PALEONTOLOGY A new analysis of fossils raises doubts about when feathers first emerged. Previously, researchers believed that Sinosauropteryx, a turkey-size beast that lived about 140 million years ago, was clad in "protofeathers" that had evolved to keep it warm.

South African researchers have reexamined the fossils and now posit that the characteristic marks on the skin are not feather remains, but are instead collagen fibers. (Collagen is a protein found in connective tissue.) If true, this means that dinosaurs didn't develop feathers as early as previously thought, and that birds evolved from a later group of dinosaurs.

How to Make Universal Blood

A new process strips donor blood of its antigens



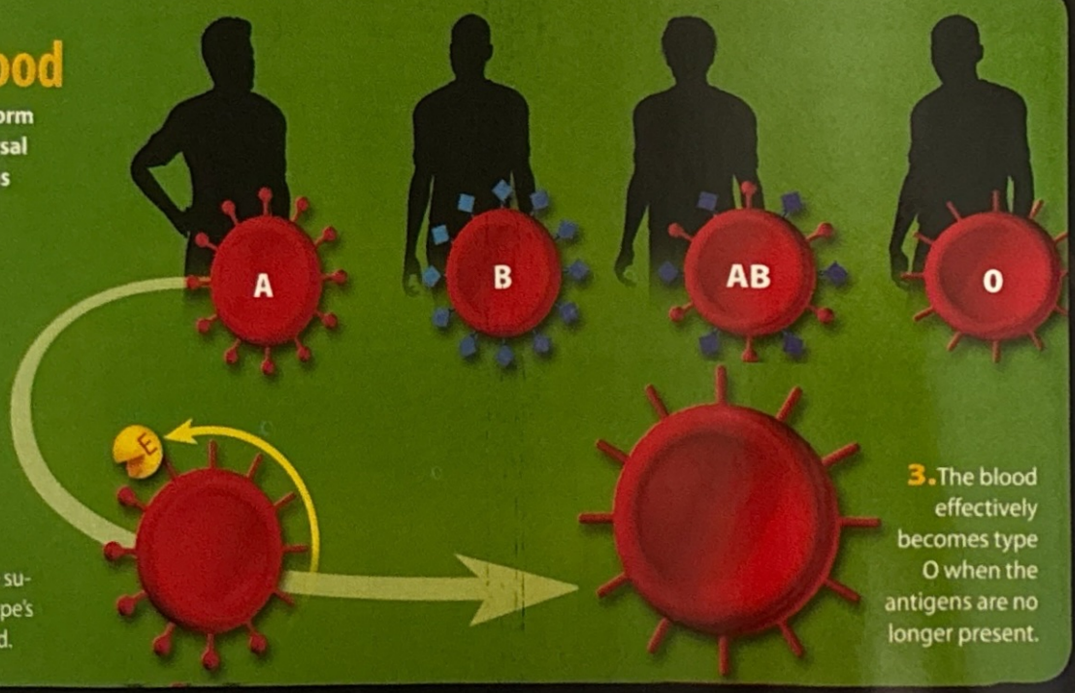
MEDICINE An international team led by Henrik Clausen of the Institute for Cellular and Molecular Medicine at the University of Copenhagen has developed a method that can transform donor blood of any type to type O, which everyone can use.

People with type O blood lack the various antigens, in the form of sugars on the blood cells' surface, that characterize the other blood types. Type A blood has one kind of sugar, type B another, and type AB has both. Since our bodies may make antibodies to the sugar groups that are not our own type, only type O transfusions are universally safe, since they cannot set off a dangerous immune reaction.

Clausen and his colleagues analyzed enzymes from 2,500 bacteria and fungi species. These enzymes have the ability to chop up sugar molecules. An enzyme from one bacteria species proved especially effective at removing type A sugar, while another removed type B. The scientists then isolated and purified these enzymes, which the bacteria use to digest sugars, so they can be used to transform all types of donor blood to the desired type O.

Scrubbing Blood

Researchers can now transform type A, B or AB to the universal type O by removing antigens



1. Blood types A, B and AB each contain antigens. People with those blood types can receive blood transfusions of only the same type.

2. An enzyme that removes the sugars that make up the specific type's antigens is added to donor blood.

3. The blood effectively becomes type O when the antigens are no longer present.

Chimpanzees Demonstrate Genuine Altruism

PSYCHOLOGY Primatologists from the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, have shown that chimpanzees help others, even at a cost to themselves—a trait that had been considered uniquely human. At a center in Uganda, researchers tested 36 chimps aged three to 20 that had been raised in the wild. At the same time, the primatologists tested 36 18-month-old human children. Both groups were placed in a series of situations to see if they would help a stranger. In one experiment, an unknown person was trying to grasp something just out of her reach. A similar percentage of both apes and children helped get the object. This suggests that altruistic behavior may have arisen earlier in evolution than researchers had previously believed.

ALASKA FAIRBANKS; FUNDACION AIAPUERCA/AFP/GETTY

New Hope for Flying-Car Fans

The Dutch firm PAL-V Europe (for "personal air and land vehicle") has announced plans to bring a car/gyrocopter hybrid to market in the next few years. The vehicle has three wheels, an automobile engine—and rotor blades that stay folded up while it's on the road, but flip up and extend when it's time to fly. It's designed to drive or fly at up to 120 mph with a range of up to 375 miles on land and 340 in the air.

Until recently, Warming Island was believed to be part of the mainland.

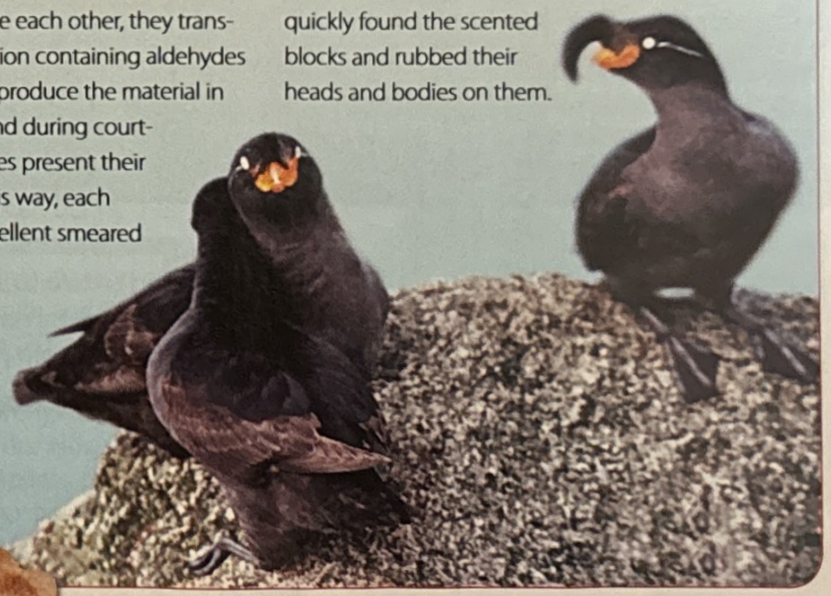
Birds Court with Insect Repellent

An aphrodisiac? No, just a way to keep parasites at bay

BIOLOGY Crested auklets entwine their necks and rub their bills through each other's plumage when courting. Now researchers from the University of Alaska at Fairbanks have discovered why—and it's not what you think.

When the birds nuzzle each other, they transfer a citrus-scented secretion containing aldehydes that repel ticks. The birds produce the material in feathers on their backs, and during courtship the males and females present their backs to each other. In this way, each auklet gets the insect repellent smeared on the parts of its own body that it cannot reach.

The researchers studied auklets in a zoo and in the birds' natural habitat on St. Lawrence Island in Alaska. In both locations, they set up fake birds and blocks of foam with artificial scent. The auklets quickly found the scented blocks and rubbed their heads and bodies on them.



"Honey, can you get my back?"

This tooth suggests that Europe was inhabited a million years ago.

A Millon-Year-Old Tooth

ARCHAEOLOGY An old molar is giving Spanish paleontologists something to talk about. The tooth, found in Spain's Sierra de Atapuerca region in 2007, is estimated at 1 million to 1.2 million years old, and thus could be the oldest human tooth ever discovered in Western Europe. This would confirm what scientists have long believed, that humans were living in Europe as long ago as a million years ago. Scientists at the Atapuerca Foundation believe that the ancient molar came from an ancestor to the species *Homo antecessor*.

Global Warming Reveals Unknown Islands

GEOLOGY The ice on Greenland is melting, exposing new, previously unknown islands along the coasts.

Most recently, Arctic explorer Dennis Schmitt discovered an island that, until now, had been covered with so much ice that it was only partially visible. The island was originally thought to be part of a peninsula connected to the mainland. For now, it's called Uunartoq Qeqertoq, which means "warming island" in the Inuit language.

This is not the first time that what appeared to be mainland along the Greenland coast turned out to be islands—and it will probably not be the last. With a 27,000-mile-long coastline dotted with inlets and a mainland covered with 630,000 cubic miles of melting ice, Greenland probably hides many undiscovered islands awaiting adventurous polar explorers.

With the help of its silk, the water spider builds an underwater home that also functions as an oxygen tank.

Underwater Homespun Habitat

A silken "lung" holds oxygen under water

BIOLOGY The European water spider has found another application for its silk. It uses the material to construct underwater tanks, which it fills with air. The spiders can use the chambers as aquatic homes, where they can hide, eat, mate, and lay eggs, living an entirely aquatic existence.

Until now, it was unclear if the spiders used air merely to create a water-free area or if they used the air for breathing, too—so biologists investigated whether the spiders would work to keep the right concentrations of gases in the chamber. Their experiments revealed that the water spiders controlled air quality in the chamber by monitoring carbon dioxide levels. If the concentration got too high, the spider would fetch more fresh air from the surface by trapping air bubbles in short hairs on their abdomen and legs.

The study shows that the water spider uses the chamber as an oxygen reservoir, in addition to other functions. Scientists also think the chamber could be an external lung, or diving tank, that has helped water spiders to conquer a completely different environment than the one in which they originally evolved. The water spider is the only known animal that collects and regulates air in an underwater chamber.

IN BRIEF **It's better to be plump and fit than thin and unfit.** A new study doesn't say it's OK to be fat but states that being slim alone won't prevent health woes.

Creativity Rises with the Ceiling

Open Spaces Promote Freer Thinking

PSYCHOLOGY Joan Meyers-Levy of the University of Minnesota and Rui Zhu of the University of British Columbia have released findings revealing that ceiling height affects how people think. They asked subjects to solve problems in rooms with 8- and 10-foot ceilings. When the ceiling was higher, subjects produced "freer, more abstract thinking"; low ceilings made them focus on details.

The researchers conjecture that people will tend to feel freer in a high-ceilinged room. This, in turn, prompts them to engage in more-abstract thinking.

That's One Sexy Spacesuit

When American astronauts return to the moon one day, they may be wearing more flexible spacesuits that offer greater mobility than classic models. The new suit, developed by Dava Newman, a professor of aeronautics and engineering systems at the Massachusetts Institute of Technology, consists of many layers of textiles molded tightly to the body. Dubbed the BioSuit, it's supported by a stiff "skeleton" in the places where the suit does not need to be particularly flexible.

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7. Being ignored and ridiculed by the friends who think you've lost your mind.
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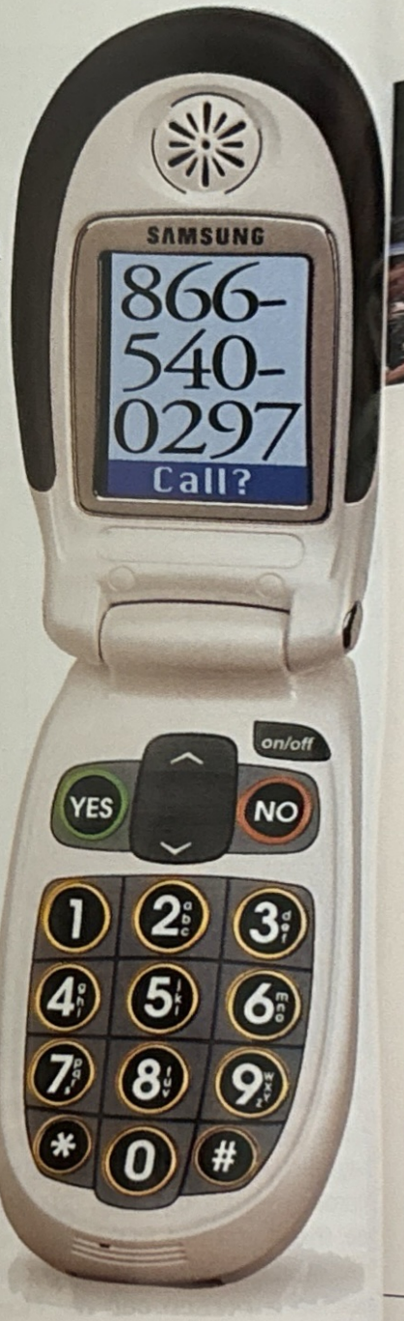

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NATURAL HISTORY MUSEUM, LONDON (2)

Ask Us

Can you really behead someone with a sword?

Separating the head from the rest of the body in one blow demands a strong, sharp sword. The swords of ancient Romans, Medieval European knights and the Japanese samurai were all strong and sharp enough to slice clean through the neck. But it's unlikely that beheadings happened often on the battlefield. In addition to a sword's strength and keen edge, an extraordinarily powerful and well-aimed blow is required. Beheadings with swords have been a common method of execution, historically, but more than one blow is sometimes needed.

HOW MUCH ENERGY DOES WIND CONTAIN?

It takes energy from the sun to set the air in motion, and the wind expends that energy as it rustles trees, pushes sailboats, and spins windmills. All the wind in the U.S. holds 40 times as much energy as current consumption.

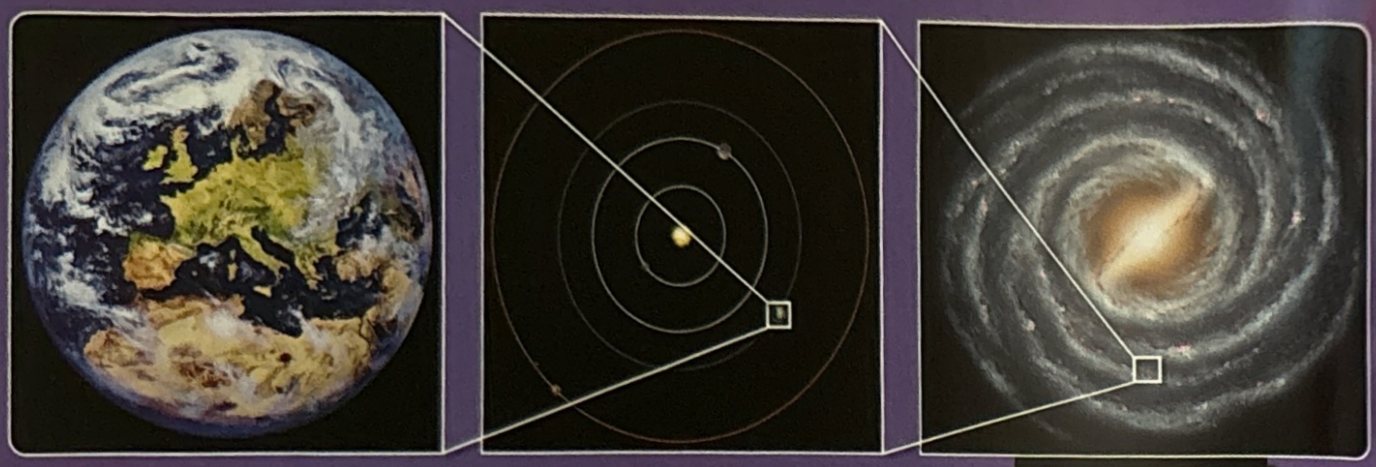
Dinosaurs may have used skin color to signify sex. As for which colors those were, we can't know for sure.

What color were the dinosaurs?

In books and movies, dinosaurs are often depicted as green, brown or gray, but scientists don't know with any certainty their actual skin color. Soft tissues like skin are very rarely preserved as fossils, and any pigments in preserved skin break down rapidly. We do have fossilized impressions of the skins of many different species of dinosaurs, however. From these, we can make out scales and folds, and it's clear that the skin of dinosaurs resembled that of modern reptiles.

Color undoubtedly played a role in dinosaur life. Just like modern animals, dinosaurs had to seek out food, avoid predators, and find mates. Scientists speculate that dinosaurs used colors for the same reasons animals do today—as camouflage, warning signs or sex markers within species. If a dinosaur lived in dense vegetation, it may have been green or brown with spots or stripes to help it blend in with leaves and shadows. Dinosaurs in open habitats may have had neutral colors similar to today's savannah dwellers, like lions.

NATURAL HISTORY MUSEUM, LONDON (2)



1,000 mph: The Earth rotates on its axis, and we rotate along with it. Speed is highest at the equator.

67,000 mph: The Earth circles the sun once a year as it completes the 587-million-mile orbit.

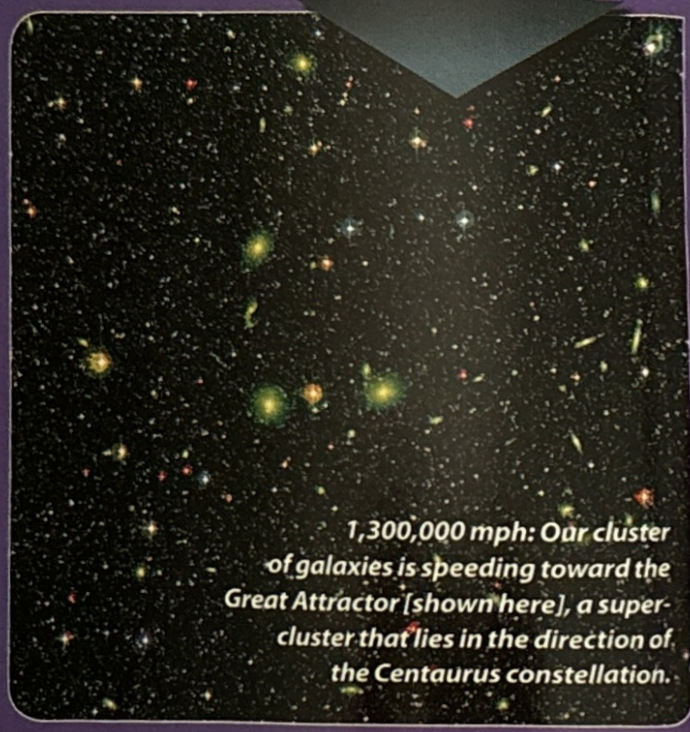
500,000 mph: The Milky Way Galaxy rotates around its center, and we move with it.

How fast are we moving in the universe?

Even if you're sitting in a chair right now, you're in motion in many ways. First, the Earth is rotating on its axis. Your velocity in this respect depends on your location. At the equator, your tangential velocity is slightly over 1,000 mph, but that reduces as you move north or south, and at the exact poles you would simply rotate in place. In addition to that movement, the Earth revolves around the sun at 67,000 mph.

Our solar system sits in an arm of the Milky Way galaxy, which makes one revolution every 225 million years. That rotation shoots us along at a speed of approximately 500,000 mph. Within our local cluster of galaxies, the Milky Way is hurling toward the Andromeda galaxy at a speed of about 290,000 mph—on course for a collision in a few billion years.

We're also being drawn at a rate of about 1,300,000 mph toward an enormous supercluster, the Great Attractor, which lies 250 million light-years away. And finally, we're expanding along with the universe. But since this amounts to space itself growing larger, it's not motion in the ordinary sense of the word.



1,300,000 mph: Our cluster of galaxies is speeding toward the Great Attractor [shown here], a supercluster that lies in the direction of the Centaurus constellation.

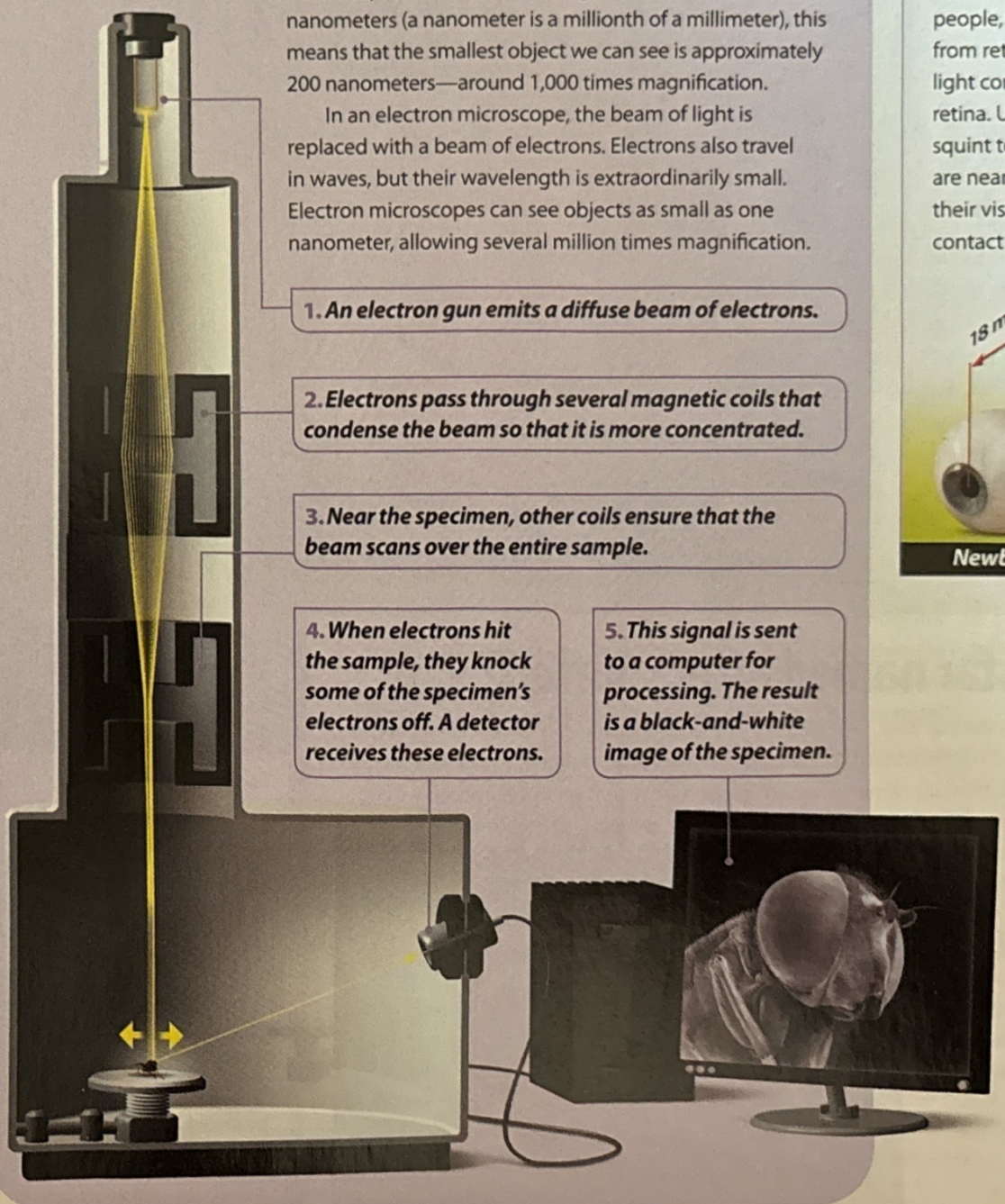
Can people feel the weather in their joints?

Research has been contradictory, but the latest studies show that the weather *can* have an effect on painful joints. A 2004 Spanish study showed that low barometric pressure—common during thunderstorms—may have a direct effect on the pressure around our blood vessels, tendons and bones, and worsened pain among patients with joint inflammation. Changes in atmospheric pressure could also cause pressure imbalances in the body that sensitize nerve endings. The same study found that low temperatures were associated with worsened pain among rheumatoid-arthritis patients. Muscles, bones and scar tissue differ in density, so cold or heat makes them expand or contract to different degrees. This can result in slight movements that are registered by sensitive pain receptors in injured joints.

How does an electron microscope work?

Electron microscopes, invented in 1932, allow us to see objects much smaller than we can through traditional light microscopes, which have been around since the 17th century. Because of the interference between light waves, we can't examine anything less than half the wavelength of the light the microscope uses. In a traditional microscope, which uses visible light of between 400 and 700 nanometers (a nanometer is a millionth of a millimeter), this means that the smallest object we can see is approximately 200 nanometers—around 1,000 times magnification.

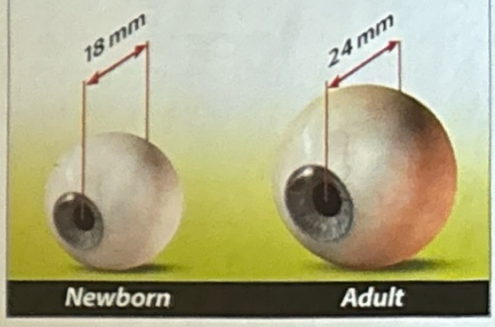
In an electron microscope, the beam of light is replaced with a beam of electrons. Electrons also travel in waves, but their wavelength is extraordinarily small. Electron microscopes can see objects as small as one nanometer, allowing several million times magnification.


1. An electron gun emits a diffuse beam of electrons.
2. Electrons pass through several magnetic coils that condense the beam so that it is more concentrated.
3. Near the specimen, other coils ensure that the beam scans over the entire sample.
4. When electrons hit the sample, they knock some of the specimen's electrons off. A detector receives these electrons.
5. This signal is sent to a computer for processing. The result is a black-and-white image of the specimen.

Is it true that eyeballs don't grow?

Measured from the cornea back to the retina, eyeballs are about 18 millimeters at birth but grow to 23 millimeters by age three. Growth slows considerably then, reaching adult size, about 24 millimeters, by puberty.

If the eyeball's growth stops too soon, a person becomes far sighted. This causes incoming light to focus at a point behind the retina. The person compensates by making a constant effort to focus, which tires the eyes easily and causes headaches. In near sighted people, the eye lengthens too much from retina to cornea, and incoming light comes to a focus in front of the retina. Unlike far sighted people who can squint to improve their sight, those who are near sighted can't see clearly unless their vision is corrected with glasses or contact lenses.



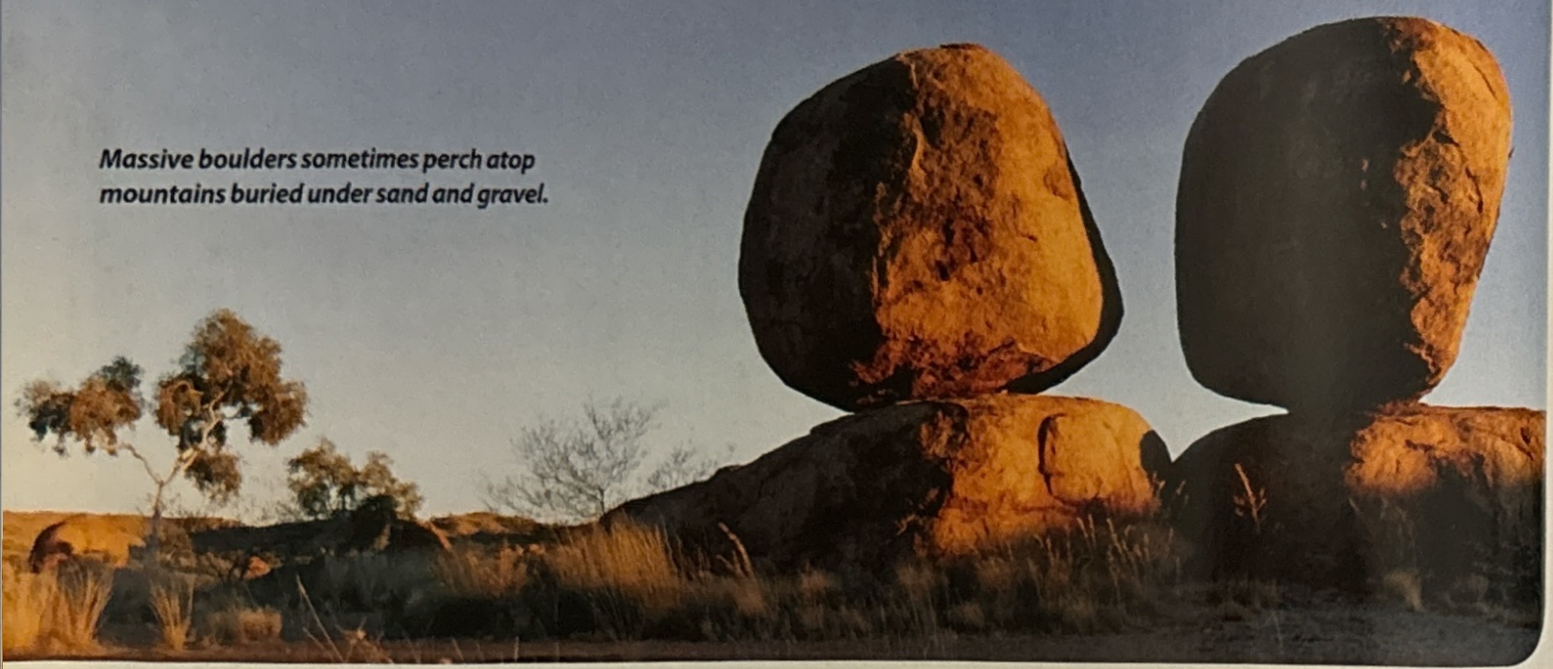
DO WOMEN TALK MORE THAN MEN?

Nope—women and men exercise their vocal faculties equally. A recent study showed that, on average, both men and women say about 16,000 words over the course of a day. There's a lot of variation between individuals, though: In a study last July of almost 400 American and Mexican college students, rates varied from 700 to 47,000 words spoken daily.

How does nature stack boulders?

All over the world, amid otherwise flat landscapes, large stones mysteriously sit on top of rock formations or other stones. These boulders are remnants of the past. The water in streams, lakes and oceans that have since dried up or shifted to new locations moved some stones to their current resting places. Others were deposited by the ice ages' immense glaciers. Just 16,000 years ago, for instance, much of the Midwest was covered with a moving sheet of ice that carried boulders along with it.

Some boulders mark the tops of buried mountains. Wind and weather erode mountains into clay, sand and stones of every size. Valleys are eventually filled in with these materials, transforming a landscape of steep mountains and deep valleys into plains sprinkled with occasional piles of large stones, which once sat atop mountains. The bedrock on which the enormous rocks lie is, in reality, the top of a mountain buried under its own sand and gravel.

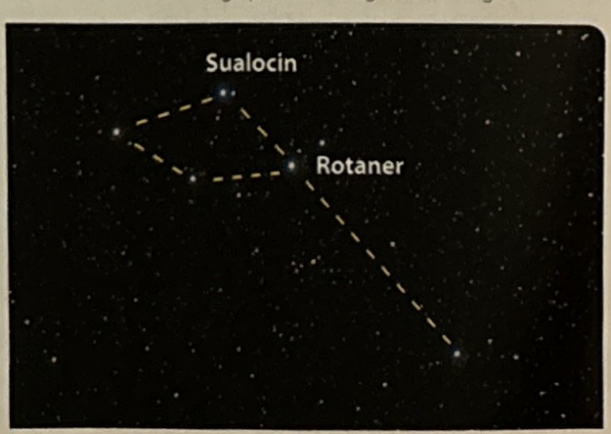


Massive boulders sometimes perch atop mountains buried under sand and gravel.

Can you have a star named after yourself?

Several companies will "name" a star after you for a tidy sum. But only one organization, the International Astronomical Union has the power to officially name heavenly bodies. But don't start writing a check. The group has determined that stars, star clusters and galaxies will only receive catalog numbers and sky positions—boring identifiers like SAO 125122. Exceptions to the rule do exist, though. Some bright stars have ancient Arabic names, and a few, such as the two brightest stars in the constellation Delphinus [right], have been given recognizable names, too.

These limitations, however, don't cover our own solar system. If you're legitimately the first person to discover an asteroid, comet or even planet, you can name it anything you want within a few limits. Astronomers believe there's much of our solar system yet to be revealed—maybe even some large planets—so get searching.



WHO INVENTED THE VACUUM CLEANER?

Englishman Hubert Cecil Booth patented a gasoline-powered machine mounted on a horse-drawn wagon in 1901. Its hoses could be run through a house's windows. Six years later, American James Murray Spangler designed a portable electric model, which was mass-produced by a cousin's husband named William Hoover.

In the early 1900's, French performer Le Pétomane reproduced entire pieces of music by farting.

Why do we fart?

Our farts are caused by gas built up in the lower intestines that passes out through the anus due to a voluntary or involuntary movement of the sphincter muscle. Some of our intestinal gas comes from the air we swallow as we eat and drink. Most, however, is nitrogen and other gases produced during digestion. The foul smell comes from bacteria in the intestines that release small amounts of sulfur-containing gases. The average person passes gas (whether noticed or not) about 14 times each day, producing between a pint and half a gallon of gas over 24 hours.

All animals need rest, but the length of sleep varies. Seals get by with a couple minutes at a time.

Do all animals need to sleep?

All animals have periods of rest and activity during the day. These biological rhythms typically follow the day's light-dark cycle and are controlled by an inner biological clock.

Arthropods, such as insects and scorpions, are the simplest animals in which some form of possible sleep has been demonstrated. They exhibit periods of reduced activity but don't seem to show the marked sudden decrease in reactions to their surroundings that we normally associate with sleep. They also do not experience the deep sleep found among mammals and birds, which have highly developed nervous systems. These animals have discrete periods of sleep with differing types of brain activity. If they don't rest, their motor functions are diminished.

The length of sleep needed varies greatly from animal to animal. Some scientists believe that diet is a factor. Herbivores like horses sleep as little as two hours a day, while carnivores like lions can sleep a whopping 20 hours in one stretch.

Scientists can't say for certain why all animals need rest. One explanation may be that sleep reduces an animal's consumption of energy and need for food. Sleep also helps animals store impressions and experiences in memory and has been shown to strengthen the immune system. Researchers are working to pinpoint the specific links between sleep and immunity.

What is fire made of, and why are flames red?

Flames look like they're material—that they have substance—so it's understandable that philosophers in ancient Greece considered fire to be one of the "elements," along with earth, air and water. They were also onto something when they divided the four elements into light and heavy, with fire and air in the former category, because flames are nothing more than glowing gases. The flames on a wax candle often contain burning, vaporized paraffin, while those from burning wood are actually the burning gases that escape from oxidized wood. Even though a typical candle flame can get up to 2,500°F, you can flick your finger through it quickly without feeling much. This is a low-tech demonstration that flames are merely a jet of burning gases and not a substance.

The color of a flame, and therefore its temperature, is determined by the amount of available oxygen and the type of fuel. Hotter flames, like those from a blowtorch, are a violet-blue, but candles, which burn cooler, often have reddish flames.

Ask Us!

Got a nagging question about science or technology? Ask the editors and experts of *Science Illustrated* at:

askus@scienceillustrated.com

Climate change, competition for resources, and other complex factors are decimating many of the world's penguin populations. Scientists and conservationists alike are battling against time to stem the damage

Penguins

Many penguin species, like the Adélies shown here, depend on the ice. Warming temperatures threaten their survival.

On Thin Ice

Where have all the penguins gone? In 1995, a census of emperor penguins (*Aptenodytes forsteri*) on the Riiser-Larsen peninsula of East Antarctica counted around 9,000 mated pairs. Five years later, at the high point of the mating season, that number had plummeted to just over 4,000 pairs. A colony of rockhopper penguins (*Eudyptes chrysocome*) in the Falkland Islands that in 1984 numbered 2.5 million pairs is now down to just 300,000. And African penguins (*Spheniscus demersus*) have lost 40,000 pairs in the past two decades. If the numbers of these and several other penguin species continue to plunge at these rates, experts fear they will be extinct within just a few decades.

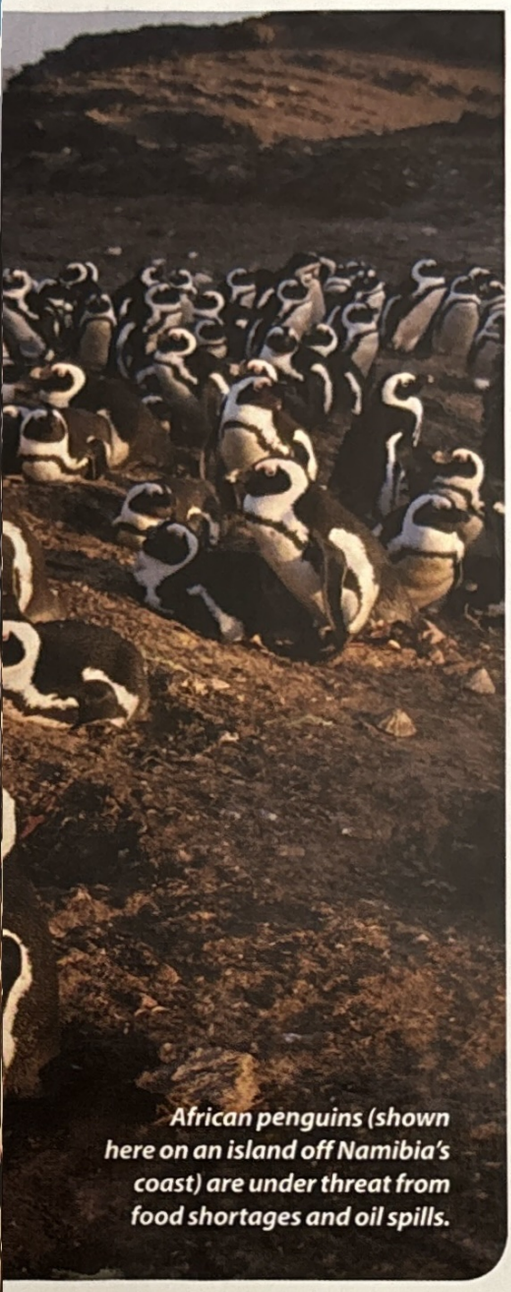
Pinning down the cause of these catastrophic declines is no easy task. Each species faces its own challenges, with multiple factors often contributing to a colony's dire circumstances. Two of penguins' biggest foes are climate change and competition with large commercial fisheries for resources. Other fierce obstacles include the destruction of the birds' habitats, poaching, and the unintentional introduction of new predators by humans.

Today, scientists and conservationists are working against the clock to unravel the problems facing penguins around the world. For many species, these humans may be the last great hope for survival.

Climate Shifts On and Off the Ice

Warmer temperatures have brought big changes for Antarctic ice in recent years—with potentially devastating results. The lifestyle of the familiar emperor penguin is inextricably bound to the ice, putting the species at risk if temperatures continue to climb. The birds mate only on ice sheets. If the ice freezes over later in the season and breaks up earlier than normal, they will have less time to mate. Their ability to find food is also threatened: If the ice sheets don't extend as far from the coast as they once did, the penguins won't be able to reach the richest feeding grounds, which are farther out to sea.

Antarctica's penguins aren't the only ones working against weather. Higher temperatures are taking their toll on the only tropical species, the petite Galápagos penguin (*Spheniscus mendiculus*). Isolated to the Galápagos Islands off Ecuador's coast,



African penguins (shown here on an island off Namibia's coast) are under threat from food shortages and oil spills.

the species is especially vulnerable, and weather changes—particularly the El Niño phenomenon—can have a dramatic effect.

During El Niño, ocean currents around the island shift. The Humboldt current's cold waters are temporarily replaced by warm, tamer waters from the equatorial current that contain less nutrients kicked up from the ocean floor. These waters sustain fewer fish, leaving penguins to go hungry. Those that don't die of starvation can have trouble finding a mate from the reduced population, resulting in a smaller next generation. Historically, El Niños have been fairly short-lived phenomena that occur only every third to seventh year or so, giving survivors an opportunity to rebuild the colony between events. But in the past few decades, El Niño periods have become more frequent and perhaps even longer-lasting. If the trend continues, the Galápagos penguins could disappear from the planet forever.

Competing for Food with Humans

Several other species—in places like the western coast of South America, the Falkland Islands and off the coast of South Africa—face starvation because of overfishing of their food supply. Rockhopper penguins are one of the hardest-hit. Just 20 years ago, the species was among the healthiest in the world, but recent years have shown an alarming decline. The Falkland Islands were once their most important breeding ground, and as late as 1984, 2.5 million mated pairs were counted there. The waters around the islands are now home to several commercial fishing fleets, and the resulting scarcity of food most likely caused the population to plunge to just 300,000 pairs today.

To preserve the species' food source, the Spheniscus Penguin Conservation Workshop, a consortium of penguin biologists, proposed in 2000 that the Falkland Islands limit commercial fishing within 30 miles of the birds' colonies instead of the current three-mile regulation. It's no surprise that the ruling government didn't accept the proposal, which would have affected the area's economy. More modest regulations, like limiting fishing-boat licenses and a 60 percent cap on the total number of fish that can be removed, have been in place since 1988—with little effect on the rockhopper population decline. ▶

Emperor penguins can dive as deep as 1,600 feet.

Five Things You Don't Know About Penguins

1 The name "penguin" may come from *pen gwyn*, Welsh words that mean "white head." The name was originally used for an extinct bird now known as the great auk that was common on both sides of the North Atlantic until the 1850s. As the story goes, when Welsh explorers first set eyes on penguins, they mistook them for look-alike auks, and the misnomer stuck.

2 When penguin parents leave the nest to dive for food, their chicks gather in a group called a crèche. Upon their return, the parents call out to their chicks. Many will respond, but the adults can recognize their own offspring by voice and appearance.

3 Penguins have salt glands that enable them to process ingested seawater. The glands, which are located above the eyes, filter salt out of the birds' bodies and excrete it through the nose.

4 When swimming at high speeds, penguins frequently leave the water in leaps that may carry them more than three feet through the air. They catch their breath in midair before reentering the water.

5 All penguins are splendid divers, but emperors wear the crown. While hunting squid and fish, their 15- to 20-minute dives can take them as deep as 1,600 feet.

Under Pressure

Of the 17 species, 12 are officially considered at-risk. The World Conservation Union (IUCN) uses several criteria when weighing an addition to its Red List. Any candidate with numbers so low that it has a 50 percent chance of extinction in the wild within 10 years will be declared critically endangered (CR), but sheer head count isn't always the deciding factor. A species can also be declared CR, for instance, if its habitat shrinks below 10 square kilometers (3.8 square miles).

The IUCN categorizes animals on its list using the following terms, from most at-risk to least: critcally endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT) and least concern (LC).

1

Magellanic
Spheniscus magellanicus
HEIGHT: **14–22 in.**
WEIGHT: **7–15 lbs.**
POPULATION: **1.3 million pairs**
STATUS: **Near threatened**

2

King
Aptenodytes patagonicus
HEIGHT: **37 in.**
WEIGHT: **30–45 lbs.**
POPULATION: **2 million**
STATUS: **Least concern**

3

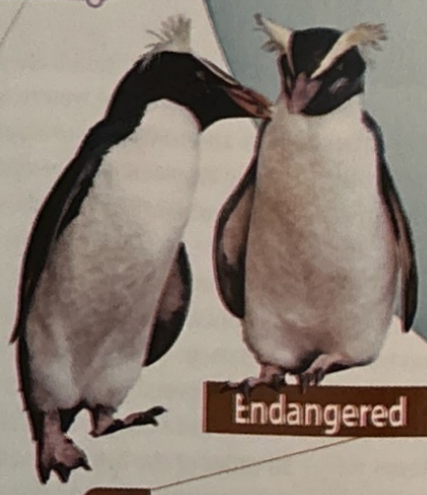
Macaroni
Eudyptes chrysolophus
HEIGHT: **28 in.**
WEIGHT: **9–13 lbs.**
POPULATION: **18 million**
STATUS: **Vulnerable**

4

Humboldt
Spheniscus humboldti
HEIGHT: **25 in.**
WEIGHT: **6–11 lbs.**
POPULATION: **3,300–12,000**
STATUS: **Vulnerable**

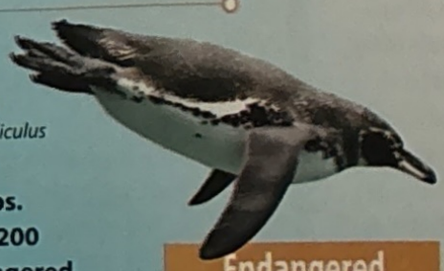
5

Gentoo
Pygoscelis papua
HEIGHT: **30–35 in.**
WEIGHT: **10–14 lbs.**
POPULATION: **314,000**
STATUS: **Near threatened**



6

Galápagos
Spheniscus mendiculus
HEIGHT: **21 in.**
WEIGHT: **5–6 lbs.**
POPULATION: **1,200**
STATUS: **Endangered**



7

Erect-crested
Eudyptes sclateri
HEIGHT: **24–25 in.**
WEIGHT: **6–8 lbs.**
POPULATION: **170,000**
STATUS: **Endangered**

8

Fiordland
Eudyptes pachyrhynchus
HEIGHT: **24 in.**
WEIGHT: **6–7 lbs.**
POPULATION: **5,000–6,000**
STATUS: **Vulnerable**

CLOCKWISE FROM TOP LEFT: M. IWAGO/MINDEN PICTURES; H. AND J. ERIKSEN/SCANPIX; RICK STEVENS/TARONGA ZOO; T. DE ROY/MINDEN PICTURES; T. DE ROY/MINDEN PICTURES; P. ARNOLD/FOCI; D. USHER/ARCO IMAGES; P. OXFORD/NATUREPL; M. IWAGO/MINDEN PICTURES; GLOBE: MIKKEL JUUL JENSEN ; FACING PAGE, CLOCKWISE FROM TOP LEFT: G. DOUWMA/NATRUEPL; G. DOUWMA/NATRUEPL; S. ZANKL/NATRUREPL; M. IWAGO/MINDEN PICTURES; M. JONES/MINDEN PICTURES; F. LANTING/MINDEN PICTURES; K. WOTHE/MINDEN PICTURES; F. BAVENDAM/MINDEN PICTURES; T. DE ROY/MINDEN PICTURES

9

Adélie
Pygoscelis adeliae
HEIGHT: **18–24 in.**
WEIGHT: **8–10 lbs.**
POPULATION: **4–5.2 million**
STATUS: **Least concern**

10

African
Spheniscus demersus
HEIGHT: **25–27 in.**
WEIGHT: **6–8 lbs.**
POPULATION: **180,000**
STATUS: **Vulnerable**

Vulnerable

11

Rockhopper
Eudyptes chrysocome
HEIGHT: **8–13 in.**
WEIGHT: **5–8 lbs.**
POPULATION: **7,340,000**
STATUS: **Vulnerable**

Vulnerable

12

Chinstrap
Pygoscelis antarcticus
HEIGHT: **28–30 in.**
WEIGHT: **8–10 lbs.**
POPULATION: **8 million**
STATUS: **Least concern**

13

Royal
Eudyptes schlegeli
HEIGHT: **26 in.**
WEIGHT: **13 lbs.**
POPULATION: **1.7 million**
STATUS: **Vulnerable**

14

Snares
Eudyptes robustus
HEIGHT: **25 in.**
WEIGHT: **6–7 lbs.**
POPULATION: **46,000**
STATUS: **Vulnerable**

Vulnerable

16

Little
Eudyptula minor
HEIGHT: **14 in.**
WEIGHT: **2 lbs.**
POPULATION: **500,000 pairs**
STATUS: **Least concern**

17

Emperor
Aptenodytes forsteri
HEIGHT: **36–44 in.**
WEIGHT: **55–90 lbs.**
POPULATION: **270,000–380,000**
STATUS: **Least concern**

Least concern

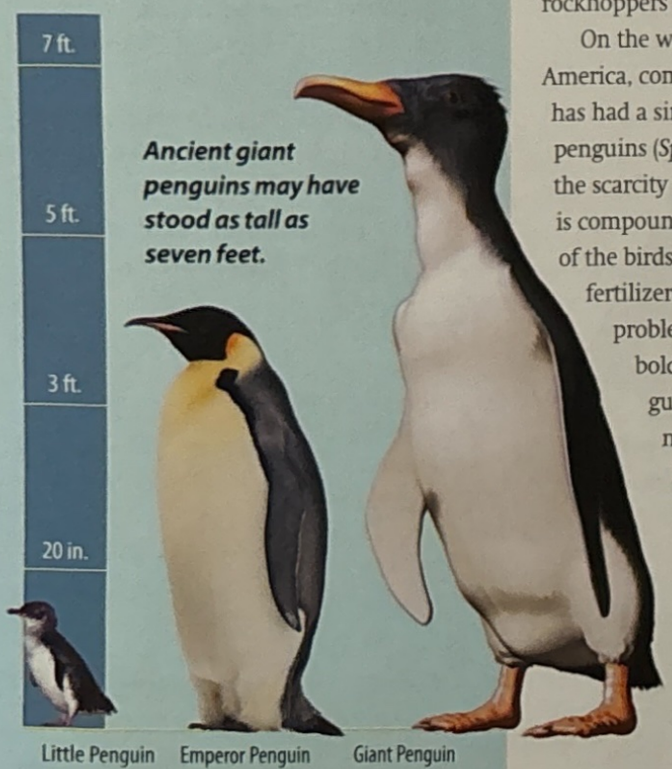
15

Yellow-eyed
Megadyptes antipodes
HEIGHT: **27 in.**
WEIGHT: **18 lbs.**
POPULATION: **4,840**
STATUS: **Endangered**

When Penguins Ruled the Roost

Penguins are a relatively new addition to our planet. The earliest fossils date back 65 million years, making them younger than most of their winged peers. Experts believe the first penguins could fly, but because the earliest fossils aren't well preserved, we can't know this with certainty. It's evident that within a few million years, penguins had completely adapted to an aquatic lifestyle.

The birds originated around New Zealand and Antarctica, boasting far more species than today. Subantarctic island excavations have shown that at one time, as many as 10 to 15 species shared a colony. The golden age for penguins came about 30 to 40 million years ago. Although many species resembled today's penguins, there's also fossil evidence of a species known as giant penguins that were as tall as seven feet and weighed 180 to 220 pounds. Giant penguins apparently enjoyed only a short stay on Earth. Experts believe they competed for food with the first toothed whales—and the whales prevailed. Whales continue to flourish, while giant penguins disappeared at least 25 million years ago.



Ancient giant penguins may have stood as tall as seven feet.

Rescue organizations around the world treat and mark vulnerable penguin colonies before releasing them back into the wild.

Rockhoppers in other areas, like the eastern coast of South America, bring the species's numbers to 1.5 million pairs worldwide. But the overall decline has been so severe that the World Conservation Union (known as IUCN for its former name, the International Union for the Conservation of Nature), has announced that rockhopper penguins are globally threatened. The group, which oversees the classification of endangered species, added rockhoppers to the list in 2000.

On the western coast of South America, commercial anchovy fishing has had a similar effect on humboldt penguins (*Spheniscus humboldti*). There, the scarcity of food due to overfishing is compounded by El Niño. Harvesting of the birds' guano, or droppings, for fertilizer has also contributed to the problem. In rocky areas, Humboldts burrow into a soft mix of guano and shells to create safe nests; removing the droppings leaves them with no place to lay their eggs. As a result of all these factors, today there may be as few as 3,000 of the birds remaining, compared with 21,000 in 1983.

Southern New Zealand's Fiordland penguin (*Eudyptes pachyrhynchus*) has been spared from food shortages and climate change, but not from invasive predators like the weka. These fierce, flightless birds were introduced to the islands off the southwestern coast of New Zealand in the early 1900s, possibly by sailors from the mainland. According to Birdlife, a global partnership of conservation organizations working to conserve birds and their habitats, wekas eat up to 38 percent of the penguins' eggs and 20 percent of their chicks on Open Bay Island, one of the Fiordlands' main breeding sites. Dogs, cats and rats also take their share. Altogether, non-native predators have helped to reduce the Fiordland penguin population to just 3,000 pairs.

Research: The First Step

It's clear that each penguin species has its own unique set of challenges. Tackling the birds' plight therefore requires extensive research. The best place to start is the penguins themselves. In 1911, one of the world's first penguin researchers, the British explorer Apsley Cherry-Garrard, ventured onto the treacherous Antarctic ice in search of emperor penguins and their eggs. The species breeds in midwinter, so he had to forge through howling winds and –70°F temperatures to collect eggs for London's Natural History Museum. Five men died during the historic expedition—just the second to attempt to reach the South Pole—but Cherry-Garrard

Emperor penguins enjoy a stroll at Japan's Asahiyama Zoo.

succeeded in bringing the first emperor penguin eggs to civilization.

Rory Wilson, head of the Institute of Environmental Sustainability at Swansea University in Wales, is following in Cherry-Garrard's footsteps. He has spent almost three decades studying several species, but since 1994, his focus has been mainly on the Magellanic penguins (*Spheniscus magellanicus*) of South America's Patagonia region. Wilson's research has been a vital contribution to our knowledge of the underwater life of penguins. Using an electronic instrument package attached to a penguin's back, Wilson can track where the bird swims, how deep it dives, how much energy it uses, and how much it eats. His recent study of Magellanic penguins revealed that the birds may consume three times as much food as was previously estimated—a finding that will undoubtedly influence efforts to maintain the at-risk species' food supply.

Signs of Hope

Beyond research, conservation groups around the world are taking action to protect imperiled species. Several private organizations have made major efforts to save the African penguin, which is under attack from a variety of threats. The species's populations are mainly concentrated in two areas off the coast, so problems tend to have widespread impact. Commercial fishing plays a role, as do predators, like feral cats, and oil spills (many colonies are located near shipping ports). One group, the South African Foundation for the Conservation of Coastal Birds, rescues and cleans birds hurt in shipping accidents and oil spills. Over the past four decades, the organization has treated more than 83,000 seabirds. Last November, workers rescued and hand-reared 400 starving African penguin chicks rescued from Dyer Island Nature Reserve in South Africa.

Thanks to human intervention, the yellow-eyed penguin (*Megadyptes antipodes*) is making steady progress. With just over 1,500 breeding pairs, it's the rarest penguin species after the Galápagos. Yellow-eyed penguins are native to New Zealand's forest and coastal scrub, a landscape often cleared for farming and trampled by livestock. Non-native predators, such as weasels, ferrets and dogs, have also been introduced there, and they have ravaged penguin eggs, chicks and adults.

Since 1987, the year the Yellow-eyed Penguin Trust was formed in New Zealand, the situation has improved. Many deforested areas on the coast have been replanted, and feral predators have been controlled. There's still a risk, but the population is growing, and the IUCN may reduce the species' endangered status within the next few years.

And while some at-risk penguin populations are showing improvement, other species never showed signs of decline. The leader of this stable pack is the chinstrap penguin (*Pygoscelis antarcticus*), which currently numbers eight million. Adélie (*Pygoscelis adeliae*) and king penguins (*Aptenodytes patagonicus*) are also going strong, with populations at five and two million, respectively. Researchers believe the chinstrap and king penguin populations may even be growing.

What's the secret of their success? It may have to do with diversification: All three species are highly adaptable, with breeding colonies throughout most of the islands surrounding the Antarctic continent and as far north as South America. Ultimately, much of the hope for penguins may rest with these bountiful birds. ■

Earth's Orbital Junkyard

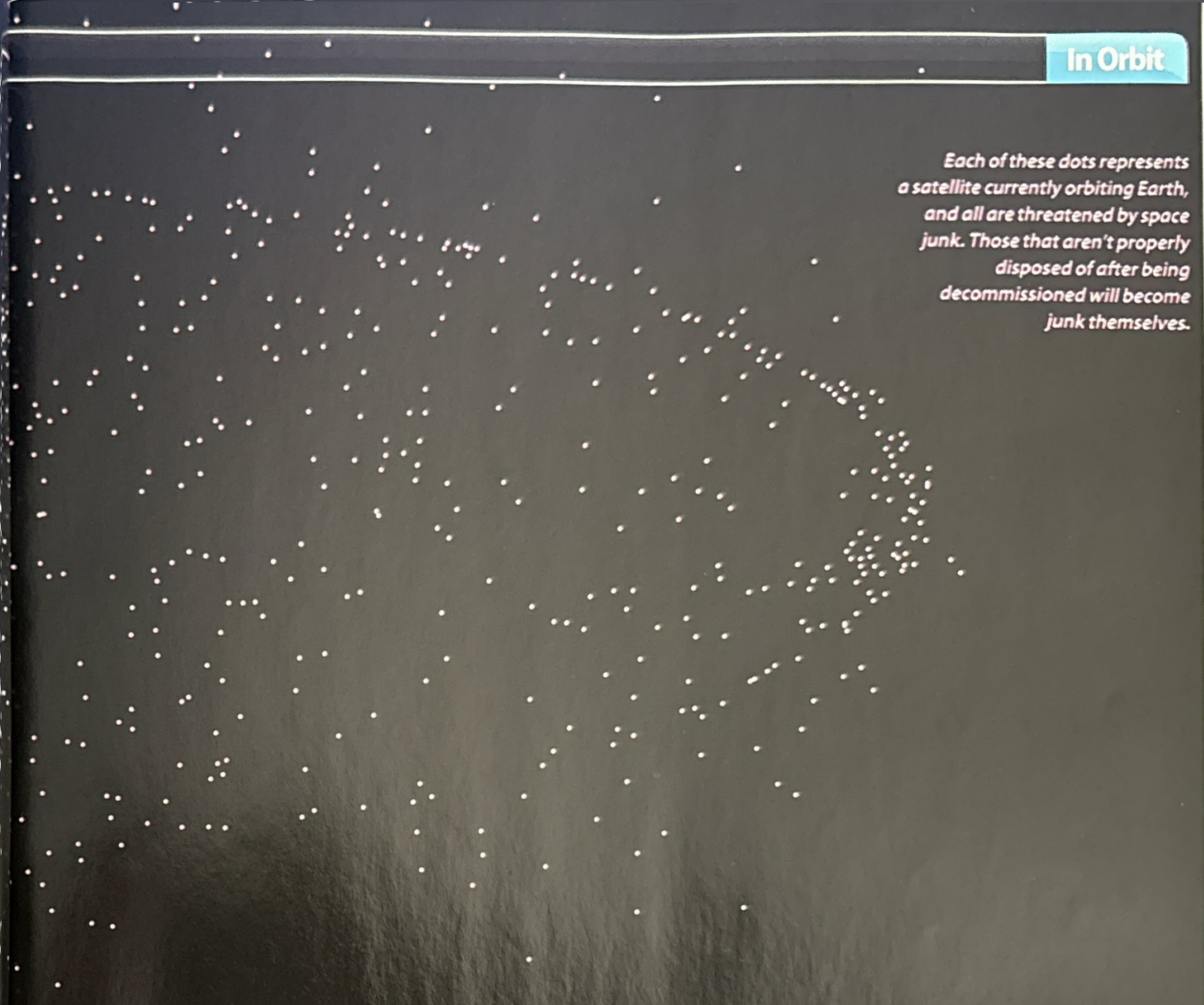
Space is littered with refuse left by 50 years of rocket and satellite launches. Scientists keep a close watch on the trash in order to protect functional orbiting equipment—and their research—but as the debris accumulates, the need for a cleanup grows more desperate

When the Soviet Union launched the satellite *Sputnik* on October 4, 1957, the space surrounding Earth was essentially empty and pristine. Today, it's a floating junkyard. After more than 4,500 launches, 3,100 satellites are still orbiting Earth, but only about 40 percent of them are still in operation. Adding to the trash heap are thousands of fragments of rockets, fuel tanks and worn-out equipment, along with millions of pieces—large and small—of metal, soot and paint that have chipped off old satellites and rockets.

This junk isn't just harmless litter, but rather a real threat to operational satellites and the research they produce. Space junk is frozen and hard, and zips along at speeds upward of 14,400 miles per hour (anything that doesn't move fast enough plummets through Earth's atmosphere). Although collisions are rare, a piece of scrap just a fraction of an inch in size can destroy a satellite component, and microscopic fragments can slowly sandblast satellites' surfaces and solar panels, wearing them down over time.

The damage is taking its toll. On May 22, last year, an unidentified object punched a hole in a thruster in Meteosat-8, a weather satellite 22,500 miles over West Africa; it's now been demoted to backup status behind Meteosat-9. And when the solar panels from the Hubble Space Telescope were replaced in 2002, NASA found 725,000 distinct impact sites they had accumulated in the course of eight years in space. The collisions hadn't destroyed anything outright, but each battering made the solar panels less and less effective.

Even if all satellite and rocket launch



Each of these dots represents a satellite currently orbiting Earth, and all are threatened by space junk. Those that aren't properly disposed of after being decommissioned will become junk themselves.

es were halted today, space junk would continue to multiply. Calculations show that there is so much trash in orbit that chunks and bits have begun to collide and break into new pieces before they can fall out of orbit and burn up in Earth's atmosphere.

Solution 1: Track the Junk

The first step is identifying the location of each bit of garbage so that researchers can direct satellites out of harm's way. In 1957, the year *Sputnik* was launched, the U.S. began using satellites, radar and telescopes to keep track of pieces bigger than four inches wide. So far, the U.S. has identified almost 12,000 pieces. The effort is paying off: Last June, NASA moved the Terra satellite just over half a mile to avoid a 15-inch-wide piece of scrap.

As scientists track the debris, they can actually watch it increase. On January 17, 2005, for example, a fragment of a Chinese rocket hit part of an old American rocket, knocking off three chunks and a multitude of smaller bits.

Outer-space explosions are also adding to the problem. Out-of-service spacecraft abandoned without first being emptied of fuel set the stage for just such an explosion in 1996, when an American fuel tank that was cast off from a non-functioning 1994 Pegasus rocket put 713 large pieces and countless smaller ones into orbit. And in January 2007, China blew up its old Fengyun-1C weather satellite during an anti-satellite weapons test, increasing the amount of junk orbiting Earth. At impact, there were more than two million pieces of various sizes, but most burned up in Earth's atmosphere. Only a small percentage of the pieces remain.

SPACE-JUNK STATS

- ***We are aware of 11,875 pieces of space junk more than four inches across, hundreds of thousands of pieces between half an inch and four inches across, and millions of even smaller fragments.***
- ***Most litter lies within 1,200 miles of Earth—especially in orbital paths 500, 620 and 930 miles up.***

To help other space programs prevent collisions, the United Nations Office for Outer Space Affairs provides member nations with the launching state, launch date and location, and basic orbital parameters of all objects sent into orbit by member nations. The Air Force also maintains a public Web site with information on objects being tracked, which satellite operators can use to keep their spacecraft out of harm's way.

Solution 2: Shield Satellites

Another way engineers are coping with space junk is by plating new satellites with armor. But every gram of material added to a satellite makes it more expensive to put into orbit, and launch vehicles can handle satellites only up to a certain weight. So it's crucial that armor be light and judiciously applied to cover just the most vulnerable surfaces. Systems needed only on the way into orbit, for instance, do not need protection. Neither do parts of the craft that are already adequately shielded behind solar panels and other potentially protective equipment.

The most common defense is a shield placed approximately an inch above the surface it protects. Shield materials can vary and are chosen for their mechanical robustness under typical orbital conditions, but aluminum is most commonly used. A piece of aluminum debris larger than 1.5 millimeters wide and traveling just shy of five miles per second—the normal velocity for objects in near-Earth orbit—can pierce a six-millimeter-thick aluminum shield.

When a piece of junk penetrates a shield, it shatters and continues toward the satellite's surface. It's unlikely that any of these smaller pieces will be able to break through that surface. Nevertheless, designers sometimes put layers of Kevlar, ceramic fabric or other materials between the shield and the satellite to slow down the pieces.

Solution 3: Properly Retire Old Equipment

Another strategy is to reduce the amount of debris in the most congested areas: the low-Earth orbits under 1,200 miles above Earth's surface, and the geostationary orbits, which lie 22,000 miles directly above the equator. Fortunately, litter less than 300 miles above Earth stays up only a few months before it loses altitude and falls into Earth's atmosphere, where friction between the object and the atmosphere causes it to burn up.

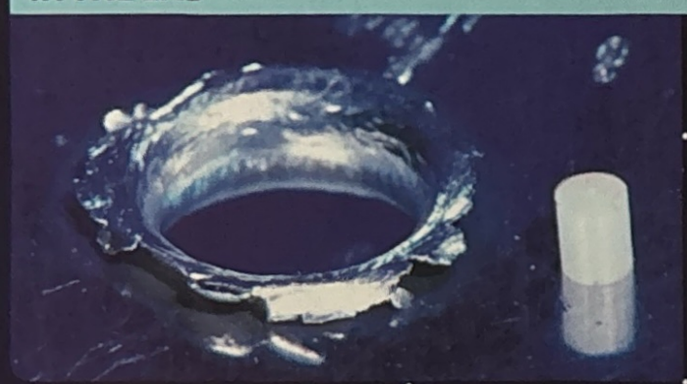
If a piece of equipment is nearing the end of its tour of duty, operators can fire the steering rockets onboard to push it down into the atmosphere, or they can push it up into a much higher zone, the so-called "graveyard orbit," where it can orbit the planet far from other working satellites. This is often the option for satellites in geostationary orbit. These satellites must be slowed down to half of their 7,000mph speed to become caught up in the atmosphere. But accelerating them by just 25 mph pushes them up out of this densely packed orbit. Not all satellite operators are so conscientious, though: More than 1,000 satellites currently pack the geostationary orbit space, but just 400 of them are actually in use.

In 1993, several of the world's space programs formed the Inter-Agency Space Debris Coordination Committee with the mandate to collect and share information. Their biggest goal: to make sure equipment leaves orbit within 25 years of its decommissioning. ■

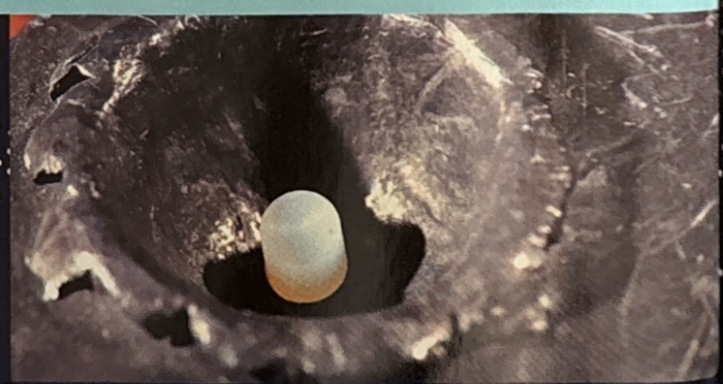
Even the Tiniest Debris Is Dangerous

A collision with a small fleck of paint or aluminum sounds harmless. But space junk can travel nearly 11 miles per second. That's 38,000 mph, which is 19 times the velocity of a bullet. A head-on collision with a one-eighth-inch-wide piece of litter unleashes a violent amount of energy. And even a fleck of paint one tenth that large can smash through a one-eighth-inch-thick metal plate, releasing a cloud of tiny particles into the satellite's internal electronics.

IN THE LAB



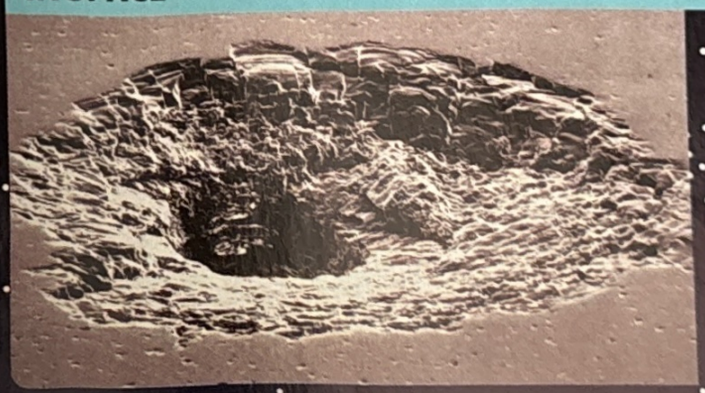
This 79-milligram nylon pellet was shot at an aluminum plate in a vacuum at three miles per second. The pellet went right through the plate.



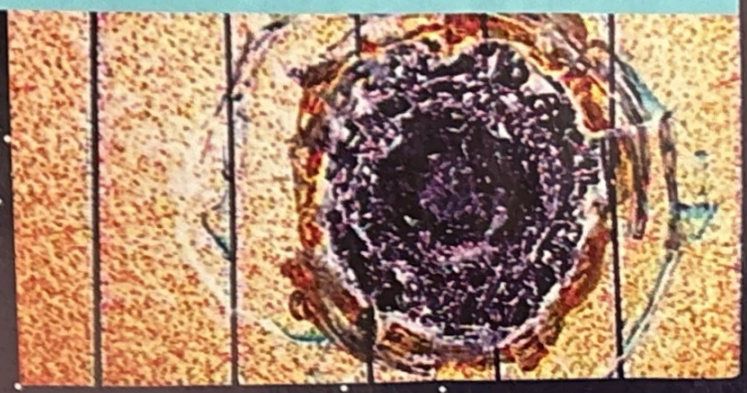
The same size nylon pellet shot at high velocity blasted a deep crater in a thick lead block.

The Hubble Space Telescope, with its golden solar panels, is just one target for the chunks of trash hurtling through outer space.

IN SPACE



A tiny chip of paint is believed to have created this crater, one tenth of an inch deep, in the windshield of the space shuttle Challenger.



After eight years in orbit, the Hubble Space Telescope solar panels showed scars from more than 725,000 impacts by debris.

A HISTORIC ERUP

Thousands of years ago, the island now called Santorini was nearly blown out of the Mediterranean Sea by one of the most powerful volcanic eruptions in recorded history. Until now, researchers believed that the eruption occurred around 3,500 years ago. But new findings indicate that it happened close to a century earlier, forcing archaeologists to rewrite the history books

Back in the Bronze Age, the Greek island of Santorini, then known as Thera, was torn apart by a gigantic volcanic eruption. It sent ash clouds 20 to 25 miles up into the atmosphere, covered the island with a thick layer of volcanic rock called pumice, and caused a 40-foot-high tsunami that hit Crete 70 miles to the south. But when exactly did this event occur? The precise date is critically important to understanding the interactions between the young empires of the Eastern Mediterranean—empires that were the foundations of early Western civilization. And, because the eruption laid down a layer of ash throughout much of the Mediterranean world, pinpointing the year of the explosion can help date other events, artifacts and ruins far from Santorini itself.

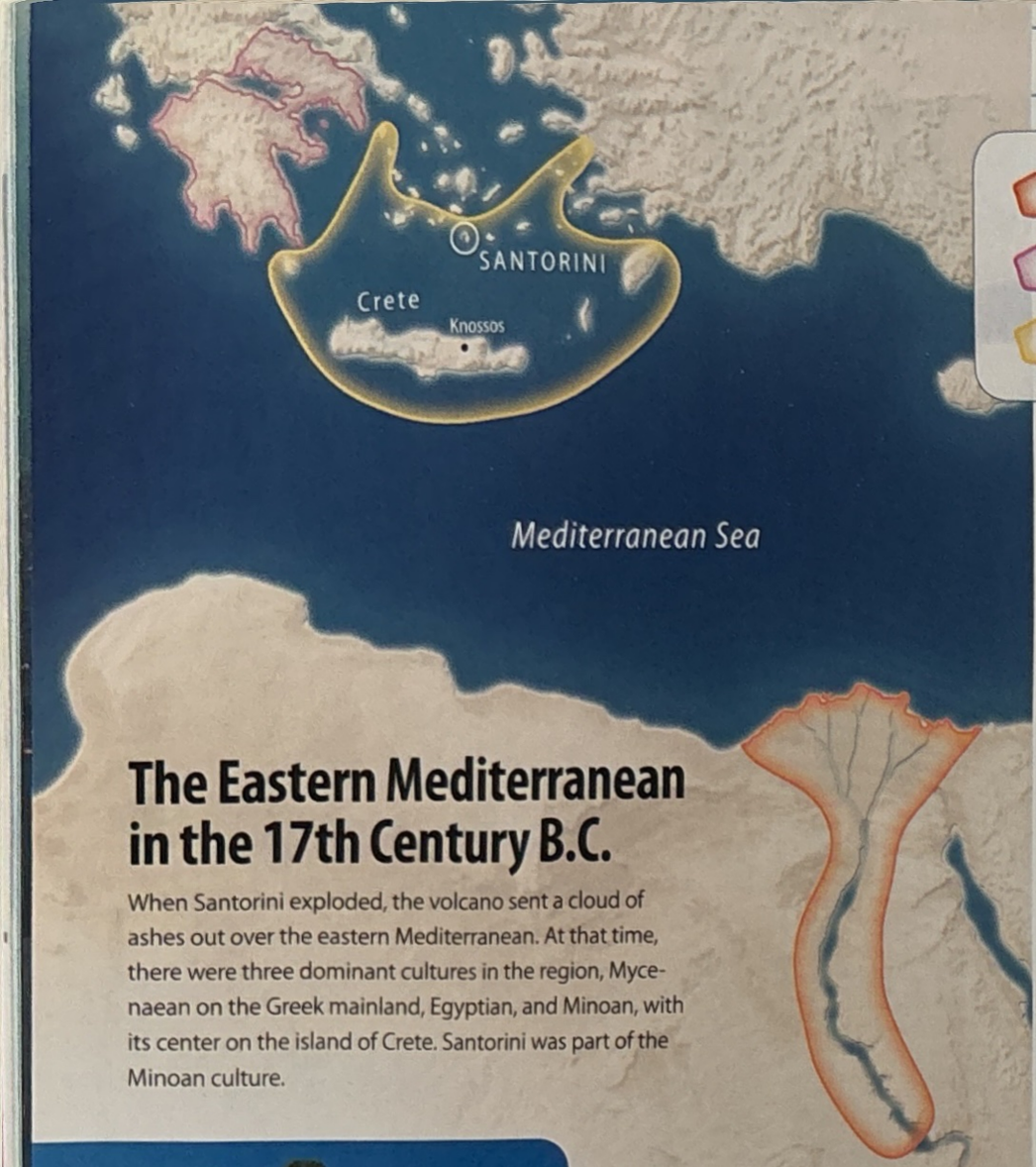
The eruption on Santorini was more powerful than Indonesia's 1883 Krakatau volcanic explosion, which killed 36,000 people. It may also have been as powerful as the biggest known eruption in human history, which occurred at the Tambora volcano on the Indonesian island of Sum-

Today's Santorini is what remains of the original island. In the center of the bay, a little island is growing out of the water—an indication that the volcano is still active.

TION

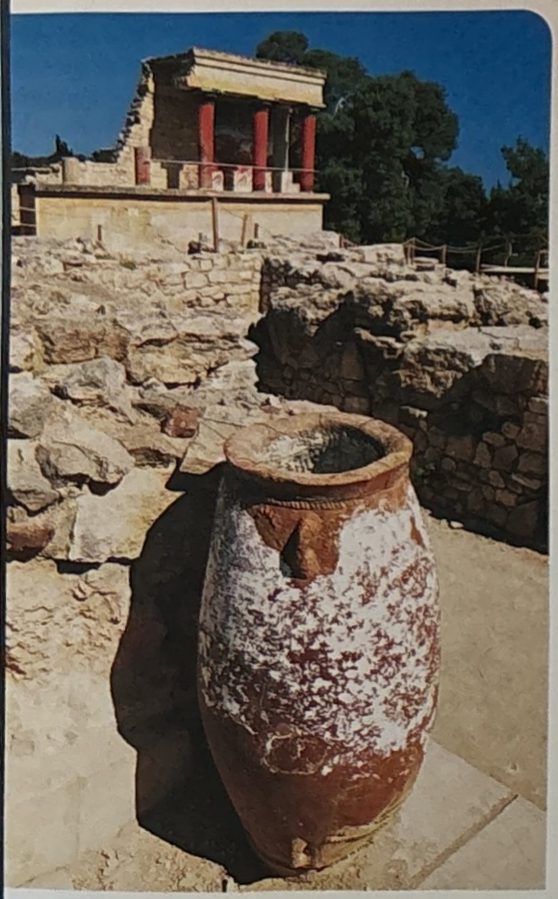
The Explosion Tore Away a Large Chunk of the Island

Before the eruption, Santorini, or Thera, as it was then known, originally wrapped around into a large circle, with an opening to the southwest. A small island lay in the bay. The island in the bay was blown away, along with parts of the surrounding circle of land.



The Eastern Mediterranean in the 17th Century B.C.

When Santorini exploded, the volcano sent a cloud of ashes out over the eastern Mediterranean. At that time, there were three dominant cultures in the region, Mycenaean on the Greek mainland, Egyptian, and Minoan, with its center on the island of Crete. Santorini was part of the Minoan culture.



The entire Minoan kingdom, along with its trading colonies, was controlled from the palace at Knossos [shown here] on Crete.

bawa. Using the Volcanic Explosivity Index (VEI) scale, which runs from 1 to 8, Krakatau scores a 6 and Tambora and Santorini a 7.

No human remains have ever been found underneath the pumice layer on Santorini, leading to speculation that much of the population may have escaped. But the eruption buried every settlement and dwelling, and well into the 1900s, experts believed that it, and the tsunami that followed, also put an end to the famous Minoan civilization centered on nearby Crete and encompassing Santorini. Today, based on other archaeological discoveries, we know that although the ash and tsunami wreaked havoc on the area, life among the Minoans continued essentially unchanged after the eruption.

Comparisons of Greek and Egyptian artifacts buried in the pumice led archaeologists to believe that the eruption happened between 1525 and 1500 B.C. But when carbon-dating results from an olive branch discovered on the island were published in 2006, the date of the explosion was revised to 1627 to 1600 B.C., making headlines around the world. The new date forced archaeologists to rethink the timeline they had pieced together describing intercultural contact in the eastern Mediterranean region. And, if that weren't enough, ice-core-dating experts now claim with confidence that the eruption occurred even earlier.

A Key to Ancient Minoa

As far back as 3,600 years ago, the Minoan culture was one of three that dominated the eastern Mediterranean. (The group got their name from Minos, who, according to myth, was the king of Crete.) At the time of the Santorini eruption, the Minoans ruled from their palace in the Cretan city of Knossos. There they developed one of the world's earliest-known scripts, which linguists call Linear A—a system that has yet to be deciphered.

The Minoans are also known for using bull motifs in their decorations, as well as for their pottery, which changed in style over the centuries. Archaeologists use these changes to define periods in Minoan culture. The period when Santorini exploded, for instance, is known as Late Minoan IA, or LM IA, after the decorative style that is classified by graceful floral designs. Minoan culture reached its high point during this age. By then, the group had established colonies on nearby islands and was trading throughout the

eastern Mediterranean. It's unclear whether Santorini was a colony or an independent state, but thanks to a fantastic discovery made there in the 1860s, we do know that it was thriving. Buried under the pumice was an entire Minoan-era village, complete with streets, houses, furnishings and decorations.

When it was uncovered, the village, which had apparently been abandoned in haste as pumice rained down on its inhabitants, was named Akrotiri after a modern-day neighboring town. The pottery and wall decorations in the buried village all clearly indicate that the settlement dated to the Minoan LM IA period.

Making the Connections

Around that time, dramatic events were unfolding in Egypt. The country had been locked in a power struggle for the past century, and foreign kings reigned on the throne. It's unclear whether these rulers, the Hyksos, were migrants or invaders, but they may have come south to Egypt from the area now known as Syria. The Hyksos era, 1630 to 1521 B.C., has traditionally been portrayed as a dark chapter in the country's history. When Pharaoh Ahmose succeeded in ousting the Hyksos from Egypt—ushering in the era known as the New Kingdom, which lasted almost 500 years and marked the peak of Egyptian influence and power—the defeated rulers were demonized by the victors and dismissed as little more than despots and marauders.

As the Hyksos rule came to an end, Mycenaean culture on the Greek mainland was just starting to grow more powerful. The Mycenaeans were a warrior people divided into many kingdoms. They are perhaps best known for conquering Troy—an event that took place four centuries later and was the basis for Homer's *Iliad*.

When archaeologists in the 1800s excavated early Mycenaean graves, they discovered fantastically valuable objects from Egypt, as well as Minoan LM IA artifacts. Some archaeologists believed that the Egyptian items came from Pharaoh Ahmose. They theorized that the Mycenaeans were then increasing in power in the region, and that Pharaoh Ahmose gave them the goods as payment for fighting against the Hyksos. Based on the Egyptian king list [see "Which Dating Method Comes Closest?" below], this would date the artifacts in the early 1500s B.C., the beginning of the New Kingdom era.

The Minoan artifacts also found in the graves were dated to the LM IA period. They were from the same era as the artifacts found buried underneath Akrotiri's pumice. Experts believed that the eruption of Santorini and the expulsion of the Hyksos from Egypt both happened at the height of Minoan LM IA. ▶

Which Dating Method Comes Closest?

One archaeological dating method and two scientific methods each cite a different time period for the volcano's eruption. The method that turns out to be correct is crucial for understanding the history of the Mediterranean region

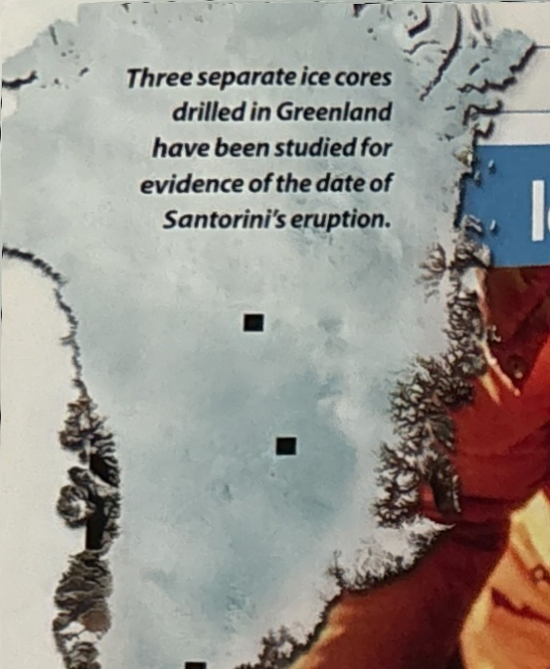
Relative Dating: 1525–1500 B.C.

METHOD 1

This sarcophagus belongs to Psamtik I, the pharaoh on which the king list is based.

Archaeologist have long accepted that the eruption of Santorini occurred 3,500 years ago. They reached this conclusion by studying archaeological finds in Greece and Egypt and by comparing them with a list of Egyptian kings' reigns. The list is a register of every pharaoh who ruled Egypt. With its help, archaeologists can distinguish between excavation layers if they encounter an object that can be linked to a particular pharaoh's reign. If, at the same time, they find objects from other cultures, they have a way to indirectly date these cultures.

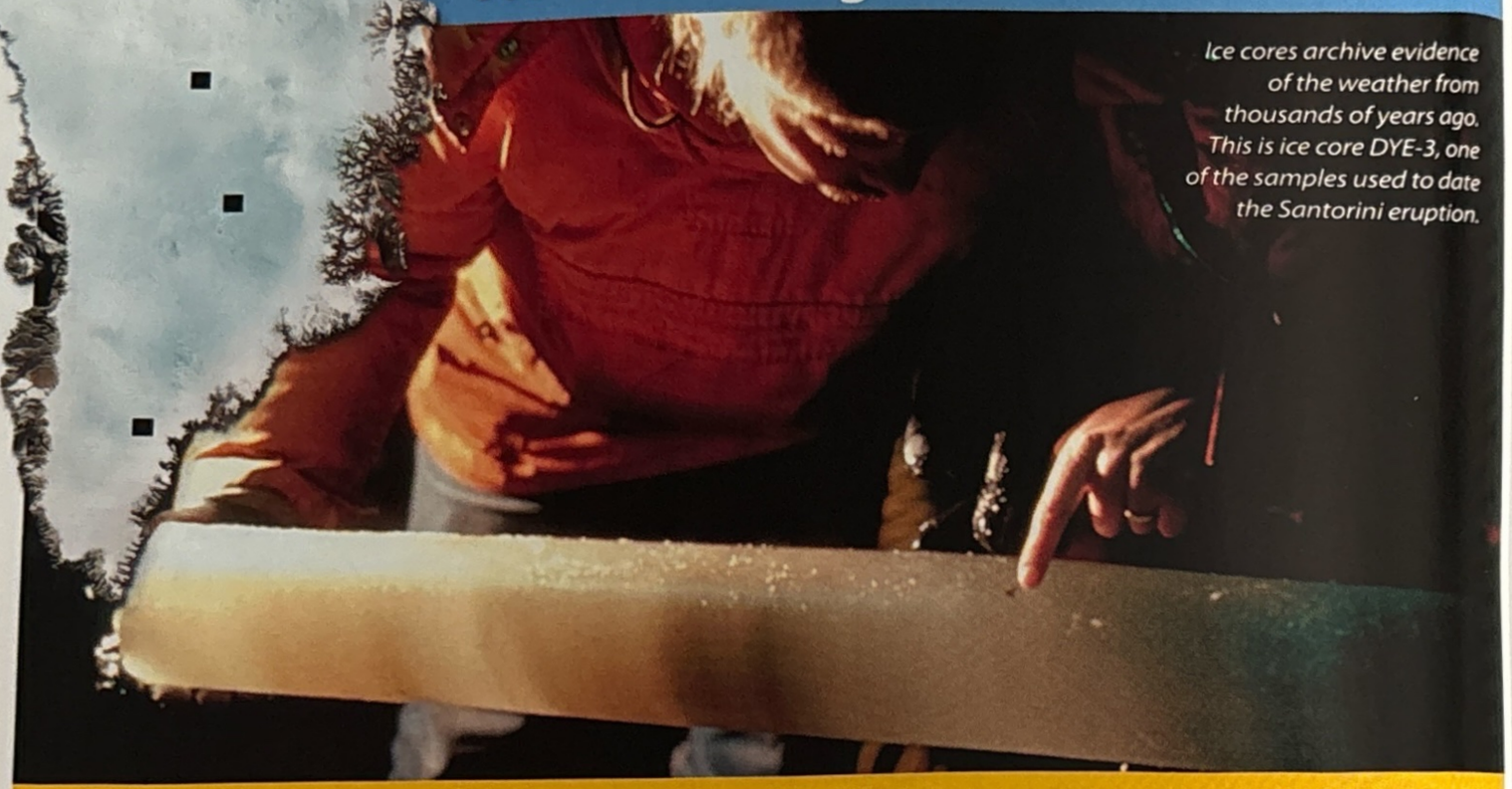
Using this method, known as relative dating, researchers assumed that the period when Minoan culture was at its height, and when the Mycenaeans were increasing in power, was contemporary with the beginning of the New Kingdom in Egypt, in the late 1500s B.C. The researchers concluded that the great eruption on Santorini must therefore have occurred during the same period, because the excavations of the buried village clearly showed that it was abandoned at the height of Minoan culture.



Three separate ice cores drilled in Greenland have been studied for evidence of the date of Santorini's eruption.

Ice-core Dating: 1647–1637 B.C.

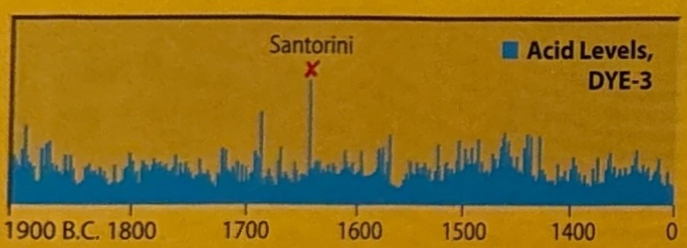
METHOD 2



Ice cores archive evidence of the weather from thousands of years ago. This is ice core DYE-3, one of the samples used to date the Santorini eruption.

The polar ice caps are enormous storehouses of information. Every year a new layer of snow falls, pressing down upon previous years' accumulation. The snow eventually compresses into ice, allowing researchers to count single years in an ice core just as annual growth rings in trees are counted.

These ice samples include traces of ancient volcanic eruptions, because each eruption sends large quantities of sulfur into the atmosphere that come back down with the snow. After exceptionally large eruptions, the precipitation over parts of the planet becomes, for a short time, more acidic than normal. And when data on the acidity of precipitation over many centuries is analyzed using a computer, each major eruption can be read as a clear "spike" on a graph. This was the case for the powerful eruption on Santorini, which three different ice core records form the Greenland ice cap indicate occurred around 1642 B.C.—a century earlier than archaeologists believe.



Rain becomes acidic after a volcanic eruption, and the acidity is deposited in the ice. On a graph, we can see Santorini's acid "spike."

Evidence from Egypt

The Egyptian king list involved in dating Santorini's eruption starts in the year 664 B.C., because we know with near certainty that Pharaoh Psamtik I founded the 26th dynasty of Egypt that year. From there, archaeologists have worked backward to about 3000 B.C., creating a list of kings and pharaohs and their reigns by comparing Egyptian records that report on pharaohs seizing power, years on the throne, kinship relationships, and victories and defeats during war. In certain cases, the king list is supported by astronomical observations. If, for example, an inscription mentions a solar eclipse on a particular day, we can, with our modern astronomical knowledge, calculate exactly what year that eclipse occurred.

Using the king list, archaeologists have been able to date layers in excavation sites when they encounter an object that relates to a particular pharaoh's reign. If they are lucky enough to find remains from other cultures in the same excavation layer, they often indirectly date those cultures as well.

With the aid of relative dating, as it's known, archaeologists believe they can make connections throughout the eastern Mediterranean. The Minoan LM IA period, as well as the era when the Mycenaeans were increasing in power, were placed in the second half of the 1500s B.C. The volcano on Santorini was therefore assumed to have exploded during this period, because the objects discovered buried at Akrotiri definitely stem from the LM IA period.

Solid Evidence from Ice?

But then scientific dating methods stepped onto the stage. When major volcanic eruptions occur, they thrust huge quantities of sulfur into the atmosphere, tempo-

rarily making precipitation more acidic than normal.

In 1987, a team of Danish scientists published their results from a deep ice core taken from the Greenland ice cap. Drilled all the way to bedrock, it provides a year-by-year record, in layered and compressed snowfalls, of the earth's atmospheric conditions [see "Ice Core Dating: 1647–1637 B.C." at left]. The researchers studied the entire length of the ice core (approximately 6,700 feet) and, as would be expected, found spikes in acidity that corresponded with the dates for known historical volcanic eruptions.

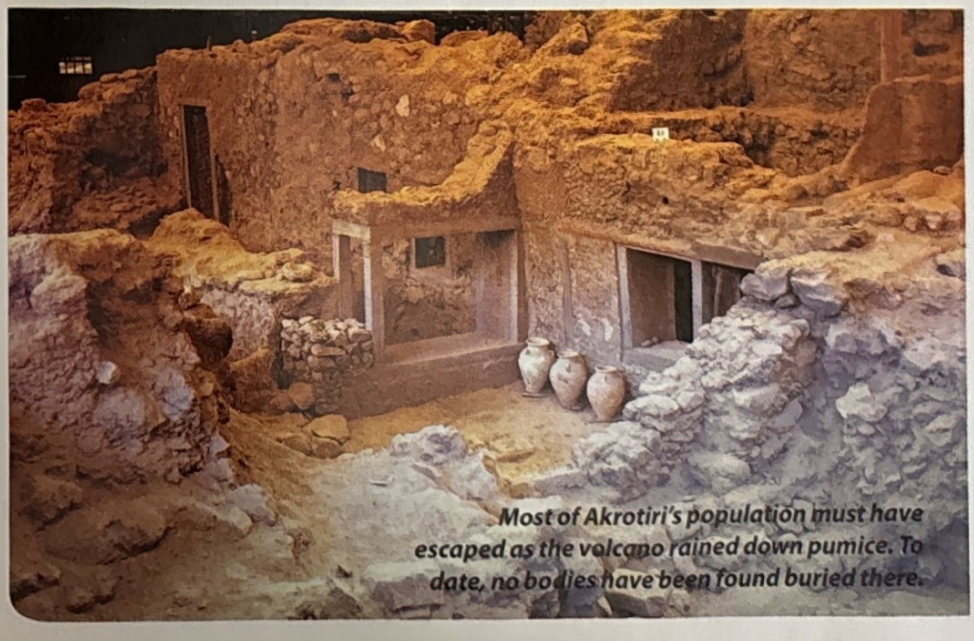
Surprisingly, no spike was found between 1525 and 1500 B.C.—when the Santorini eruption was believed to have occurred—but there was a marked increase in acidity in 1645 B.C. The researchers concluded that this was probably from the Santorini eruption. Ice-core dating is known for its precision, but critics quickly spoke out against the new data. Archaeologists assigned more worth to their research than to the ice cores. They realized that revising the date of the eruption would mean that the chronology they had pieced together for the entire eastern Mediterranean could be called into question. Some critics of the ice-core dating also said the spike in acidity in the sample could have come from an eruption in Alaska that had yet to be precisely dated. But they could not explain the absence of a Santorini spike.

And so things stood for nearly 20 years. Then, in 2006, another team of Danish researchers reported a sensational find on Santorini. A geology student had discovered an ancient olive branch embedded in the pumice layer of a hard-to-reach cliff. The branch's twigs and leaves were intact, indicating that it had been alive when it was buried. In one part of the branch, scientists were able to identify the outer annual growth rings, which would have been the last the tree produced before being buried by the eruption. They carried out a series of radioactive carbon-14 dating tests and produced a bold result: With 95 percent confidence, they said that the branch had been buried between 1627 and 1600 B.C, placing the eruption around 100 years earlier than the relative-dating estimate.

Rewriting History

There was no way out—the archaeologists had to rewrite history. Although some continue to insist on the later date, their numbers are dwindling. There are only two possibilities: Either the Egyptian king list is wrong, or there's something amiss with the connections archaeologists have made between cultures.

Most experts dismiss the first possibility. There is general agreement that the king list for the middle of the second millennium B.C. is, at the very worst, off by 10 years—not by a full century. It's far more likely that the relative-dating



Most of Akrotiri's population must have escaped as the volcano rained down pumice. To date, no bodies have been found buried there.

A Cataclysm Plays Out

A Rain of Rocks

Material from the island in the middle of the bay blasts high into the air and covers Santorini with a layer of ash and pumice up to 25 feet thick.

Hot Lava + Steam = Explosion

Millions of gallons of seawater pour into cracks and fissures opened by the eruption and meet the hot magma beneath. This causes a massive steam explosion that changes Santorini's shape and litters the island with even more rocks, debris and ash. Hot lava covers much of the remaining land.

The Center Sinks

Once the magma chamber beneath the island empties, the center part of the island sinks into the sea, creating an interior crater called a caldera. The island of Santorini that we see today consists of this ancient caldera's walls.

Radiocarbon Dating: 1627–1600 B.C. METHOD 3

Geologists found this olive branch embedded high up on Santorini's interior coastline [see arrow above]—the crater's former wall.

In 2006, Danish researchers published a report dating the Santorini eruption using an olive branch that had been buried under the ash layer laid down during the eruption. The scientists dated the olive wood using the carbon-14 method, which measures levels of an isotope of carbon found in all living matter. Carbon-14 is radioactive and decays over time, allowing scientists to measure the quantity of carbon-14 found in any object and extrapolate from that information to arrive at the object's age.

Since the entire olive branch was found intact, scientists believe that it was buried alive, giving them great confidence about their conclusions.

method is in error. It is, in fact, difficult to trace interactions between cultures. Ceramic objects, for example, can be passed down through generations and then buried with artifacts from later periods. Layers from an early era can be disturbed by subsequent human activity or dated incorrectly. In some instances, connections among cultures have been based on just a few objects; today's archaeologists are cautious about relying on older excavations not carried out to modern standards.

In the revised history, the Mycenaeans could not have been serving as mercenaries for Ahmose in Egypt when Santorini exploded. Their growing power, reflected in the rich finds discovered in their graves, cannot be ascribed to an alliance with the rulers of the New Kingdom. The Mycenaeans must instead have had some kind of trading connection to the New Kingdom's predecessors, the Hyksos. So the Hyksos period—with this evidence that they engaged in extensive overseas trade—must not have been as grim as researchers believed. Or, as archaeologist Jeremy Rutter of Dartmouth College put it in *Science* in 2006, "The Hyksos have gotten lousy press."

The LM IA period, when Minoan civilization was widespread in the region and quite advanced, was also not solely contemporary with the New Kingdom in Egypt according to the revised dates. Instead, it must have started earlier than originally thought, during the Hyksos era.

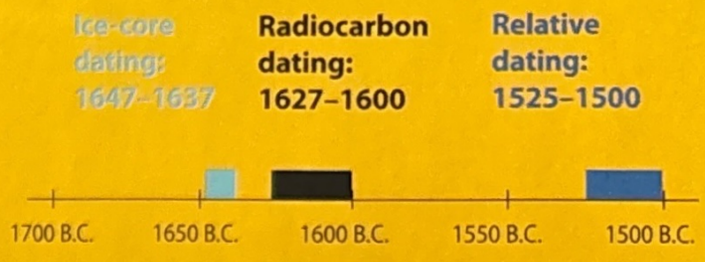
The Scientific Argument

Unsurprisingly, the debate rages on. The scientists, after all, are interested in dating the eruption as precisely as possible. Since the 1987 ice-core paper, two more Greenland ice cores have been studied. The findings, published in 2006 and 2007,

DAVE BARTRUFF/GETTY IMAGES

And the Winner Is . . .

Today, most researchers agree that two scientific methods give the most precise dates, with ice-core dating considered the most reliable. Although the dates that were established using the ice-core and carbon-14 methods do not completely agree, both place the eruption roughly in the second half of the 17th century B.C.—around a century earlier than previously established using the archaeological method of relative dating.



confirm the earlier conclusions. Aside from a three-year correction from 1645 to 1642 B.C., the ice-core experts hold fast to their claims.

There is another solid argument for the new dating: It would be downright strange if there were *no* trace of the Santorini eruption in the ice. Both Krakatau and Tambora show up clearly at precisely the dates we know they erupted, even though they are farther away from Greenland, as does the A.D. 79 eruption of Vesuvius that buried Pompeii.

In contrast with the 13-year margin of error for the olive-branch carbon dating, the ice-core dating is unlikely to be more than five years off, so it constitutes a stronger argument in favor of an eruption around 1642 B.C. This also means that there is disagreement between the ice-core dates and the carbon-14 dating.

Some archaeologists have used this discrepancy as an argument for sticking with their artifact-based dates. But ice-core and carbon-dating experts maintain that this is a weak argument. Scientific dating methods, while more accurate than relative dating, have their own small margin of error. That margin could easily result in an overlap in the dating ranges produced by the ice cores and olive branch during the second part of the 17th century B.C. As far as the scientific community is concerned, the conclusion is unmistakable: The history of the eastern Mediterranean must be rewritten. ■

Today, Santorini is a popular tourist destination, known for its villages of whitewashed homes and blue-domed churches. Many of the villages are perched on the edges of the old caldera's walls.

DAVE BARTRUFF/GETTY IMAGES

Learning to Be an ORANGUTAN

Thousands of these great apes are held captive as pets around their native Southeast Asia. Others are orphaned when bounty hunters kill their mothers. Last year, more than 100 of the endangered apes were rescued and enrolled in "orangutan school," where they will spend several years learning essential skills from humans—and one another—before being released back into their natural habitat

The Nyaru Menteng center takes in orangutans found imprisoned in homes, where they often live in miserable conditions, or those abandoned when they become too difficult to manage as pets.

The Rescue Operation

The **Borneo Orangutan Survival Foundation** runs two centers on the Indonesian part of the island of Borneo. Last year, the Nyaru Menteng center confiscated 90 apes from private homes and rescued 118 from plantations. Only 50 of those apes were ready to be released into the wild right away. The other 158 will join the hundreds of apes—from newborns to eight-year-olds—that are already being rehabilitated at the center. This year, more than 100 of the center's apes will become the first rehabbed group to return to the wild.

In the wild, baby orangutans cling to their mothers as they learn new skills.

The four orangutans are very obviously nervous. For the past several years, Inung, Gadis, Sumeh and Cakra have enjoyed a semi-protected existence in a series of progressively more challenging ape "schools" to help them make the transition from their previous life in captivity to life in the wild. But last night, the three females and one male were led from their familiar surroundings with milk and fruit into individual cages. The friends spent all night in the cages, and now, at 8 a.m., they're being loaded onto a boat.

After a short ride, the cages are opened on a small rainforest-covered island in the middle of the Rongan River. The assistants from Nyaru Menteng Orangutan Training Center are exuberant when the curious orangutans emerge from the cages. For several hours, the apes explore the island, which has everything an orangutan could wish for: trees, fruit, flowers, fresh leaves and other delicacies of the rainforest. The apes are nearing the end of years of training before being released from captivity. In the months ahead, the center's employees will supervise while these four adapt to the normal life of a wild orangutan. When deemed ready, the apes will be taken as part of a larger group to an orangutan-free wooded area where conservationists hope they will mate and contribute to the preservation of their endangered species.

Imprisoned as Pets

The story of these orangutans' lives before they arrived at the center is a sad but common one. Although orangutan trade is prohibited by international treaty, thousands of apes stolen from Borneo and Sumatra's deep rainforests live dismal, imprisoned existences throughout Southeast Asia. In many areas of Indonesia, domesticated orangutans are a status symbol. But the large-eyed charmers make for less-than-suitable pets. Adorable at first, within a few years the apes grow into much larger, dificult-to-manage animals with the strength of several grown men.

Orangutans that survive to this age can be surrendered to national authorities. The problem is that a young orangutan who has grown up as a pet in a wealthy home has no ability to fend for itself in the wild.

Other orangutans arrive at Nyaru Menteng as babies—in 2006, the Project received 89 of them—after their mothers are killed by palm-plantation workers, who are awarded a bounty for each ape they can eliminate. Orangutans have taken to raiding these agricultural operations because logging has wiped out so much of their natural habitat.

The main reason even wild baby apes need extensive training to survive in their natural habitat is that young orangutans spend seven to nine years with their mothers, learning the ins and outs of life in the rainforest. If their mother is killed before then, they're not ready to live on their own. There's a lot to take in: Their diet consists of fruit, flowers, leaves and bark from more than 400 different plants, which they must be able to distinguish from poisonous varieties to survive. Adolescent orangutans must also learn what time of year various trees flower or

The Plight of the Orangutan

In 1996, DNA tests at Lund University in Sweden showed that there are two orangutan species: Sumatran (*Ponginae pongo abelii*) and Bornean (*P. pongo pygmaeus*). Recent research indicates that between 45,000 and 69,000 Bornean orangutans and just 7,300 Sumatran orangutans remain in the wild. Both species are in rapid decline, with deforestation posing the biggest threat. In February 2007, the United Nations Environmental Program issued a report describing the orangutans' prospects as far more dire than was previously assumed. Satellite photos reveal the alarming deforestation of Borneo and Sumatra. The grim prediction: Almost 98 percent of the islands' rainforests will be destroyed by 2022—even in national parks, where the government turns a blind eye to illegal logging operations.

Orangutans live in only two places: the islands of Sumatra and Borneo, where they are threatened by logging.

Baby orangutans are popular pets in Southeast Asia, but at the Nyaru Menteng center they get a chance to return to the true life of an ape.

Borneo orangutans number in the tens of thousands, but their population is declining rapidly.

bear fruit, and how to handle challenges like the durian, an infamous Asian fruit (and a favorite of the apes) that weighs more than two pounds and is covered with spikes. It looks more like a weapon from the Middle Ages than a meal, and getting at its juicy center requires experience. They also learn how to find and eat termites and honey. And food is just the beginning—apes must learn how to avoid poisonous snakes, climb, build nests, and countless other wilderness-survival skills.

Welcome to Rehab

That's where Lone Dröscher Nielsen, who runs the rehabilitation center at Nyaru Menteng, comes in. She and her staff serve as surrogate mothers to the orangutan orphans brought to the center.

Once a newcomer arrives at the center, it undergoes an extensive medical examination to check for disease and malnourishment. (Instead of a mix of figs, flowers, fresh leaves and insects from the rainforest, imprisoned orangutans may have been raised on crackers and tea.) Apes showing any indication of illness or disease are quarantined from the others until they have recovered.

Next, the apes are divided according to age and ability. Orangutans younger than six months go to the nursery, where they play in a small forest area and sleep at night in cozy laundry baskets with padding, pillows and blankets. In the wild, baby orangutans cling to their mothers constantly. To compensate for the lack of an orangutan mother, each group of six young apes in the center is assigned two human caretakers who stay with them 24 hours a day, even sleeping (and occasionally cuddling) in the same room.

School Is in Session

The caretakers carefully note the orangutans' progress and setbacks to develop a comprehensive idea of the apes' abilities. When the little apes in the nursery are ready, usually at around six months old, they move on to Forest School One, where they are taught everything from how to climb small trees to how to open unyielding fruits such as the durian.

At this stage, the toddlers also acquire more advanced technical skills. Learning how to build their own nest—something wild orangutans do every evening—tops the list. Each afternoon, caretakers lay out branches. To get the inexperienced apes started, the center provides each one with a basket-like frame that just needs to be padded with branches. Fortunately, orangutans are expert mimics, so the young ones eventually learn the art of nesting by

observing their older and more competent cohabitants—Forest School One has apes up to three years old. At night, the orangutans might sleep in their nests or return inside to sleep in their laundry baskets.

Every day, the caretakers bring the orangutans into a forest with larger trees than those in the nursery. Here they can move around freely, swing from the trees, forage for food, and build nests. The more time the apes spend in the trees, the better, because wild orangutans rarely descend to the ground. It takes practice to move acrobatically through the tree canopy, and it doesn't get any easier with age: Few branches can carry the nearly 200-pound weight of an adult male.

When the caretakers decide the orangutans are ready, around age three, they're moved to Forest School Two. At this stage, they spend more time in the forest, hang out in bigger trees, and usually sleep outside in their nests. They stay here until they're six years old.

Finally they're ready for Orangutan University on one of three islands the center leases on the adjacent Rongan River. For the next two years, they essentially live as wild apes. They're not on their own yet, though: The center supplements their food and provides medical care if they become ill or are injured.

At the center, orangutans teach each other how to survive in the wild.

At age eight, the rehabilitated apes are considered ready for complete independence in the wild. Over 100 have reached that stage at the center, but have been awaiting a suitable forest area to become available to them. The apes can only be released into areas of Borneo with small orangutan populations; setting them free into areas with large groups of wild apes would disturb the natural order and create unfair competition. The perfect land has finally been located, and the center is in the final stages of gaining approval from the Indonesian government to release the apes. When that happens, Nyaru Menteng's rehabilitated orangutans will be swinging through the trees of Borneo, breathing new life into empty forests. ■

Lone Dröscher Nielsen spends time with the apes she works to rehabilitate.

Fighting for Great Apes

Lone Dröscher Nielsen has lived among orangutans at Nyaru Menteng Orangutan Training Center in the heart of Borneo since 1999. After stints as an au pair, private chef and flight attendant, she decided to move to Indonesia—she had fallen in love with Borneo's orangutans and their rainforest habitat during a stay on the island.

Nielsen quickly realized that there was an acute need for training centers to rehabilitate orphaned and domesticated orangutans. So she began to raise money to establish a new center in the central part of Borneo, near the apes' natural habitat. Eventually, a partnership was formed with the Borneo Orangutan Survival (BOS), a group dedicated to protecting the endangered ape. The next steps: obtaining financing from a Swiss foundation, and reaching an agreement with the Indonesian Ministry of Forestry. In November 1999, the first young orangutans were welcomed to Nyaru Menteng.

Today, the center is in peril. Funding is running out, and unless Nielsen can raise $1.5 million, it will likely be returned to the Indonesian government, and all the orangutans will be euthanized. For more information or to help, go to *redapes.org*.

Earth

LAVA RISES FROM THE DEEP

The Big Island of Hawaii rises 33,474 feet above the floor of the Pacific Ocean and lies over an unusually warm part of the Earth's interior. This hot spot has produced the volcanoes that make up the Hawaiian archipelago. The three most recently active volcanoes—Kilauea, Mauna Loa and Loihi—rise out of the spot. Other, less-active and dormant volcanoes in the archipelago used to lie here as well, but the natural movement of the Pacific tectonic plate has carried them away to the northwest. This unusually detailed image was taken primarily in the infrared spectrum, allowing us to see the volcanoes' hidden underwater bases.

THE IMAGE

Satellite: Landsat 7
Sensor: Enhanced thematic mapper plus (ETM+)
Color: Enhanced

As You've Never Seen It

For centuries, explorers have risked their lives to reach far-flung corners of the planet. Today, satellites provide incredibly sharp images of nearly every spot on Earth, so anyone can sit back and view hard-to-reach places from the comfort of their own home. Harvesting data from high-tech sensors on various international satellites, **Germany's space-research agency, DLR**, compiled these awe-inspiring and enlightening images of islands, mountains and glaciers across the seven continents. Together they are a record of our planet in action—erupting, melting, colliding, cracking. Here, a look at some of the most impressive satellite images of the past 20 years.

A MOUNTAIN DISAPPEARS

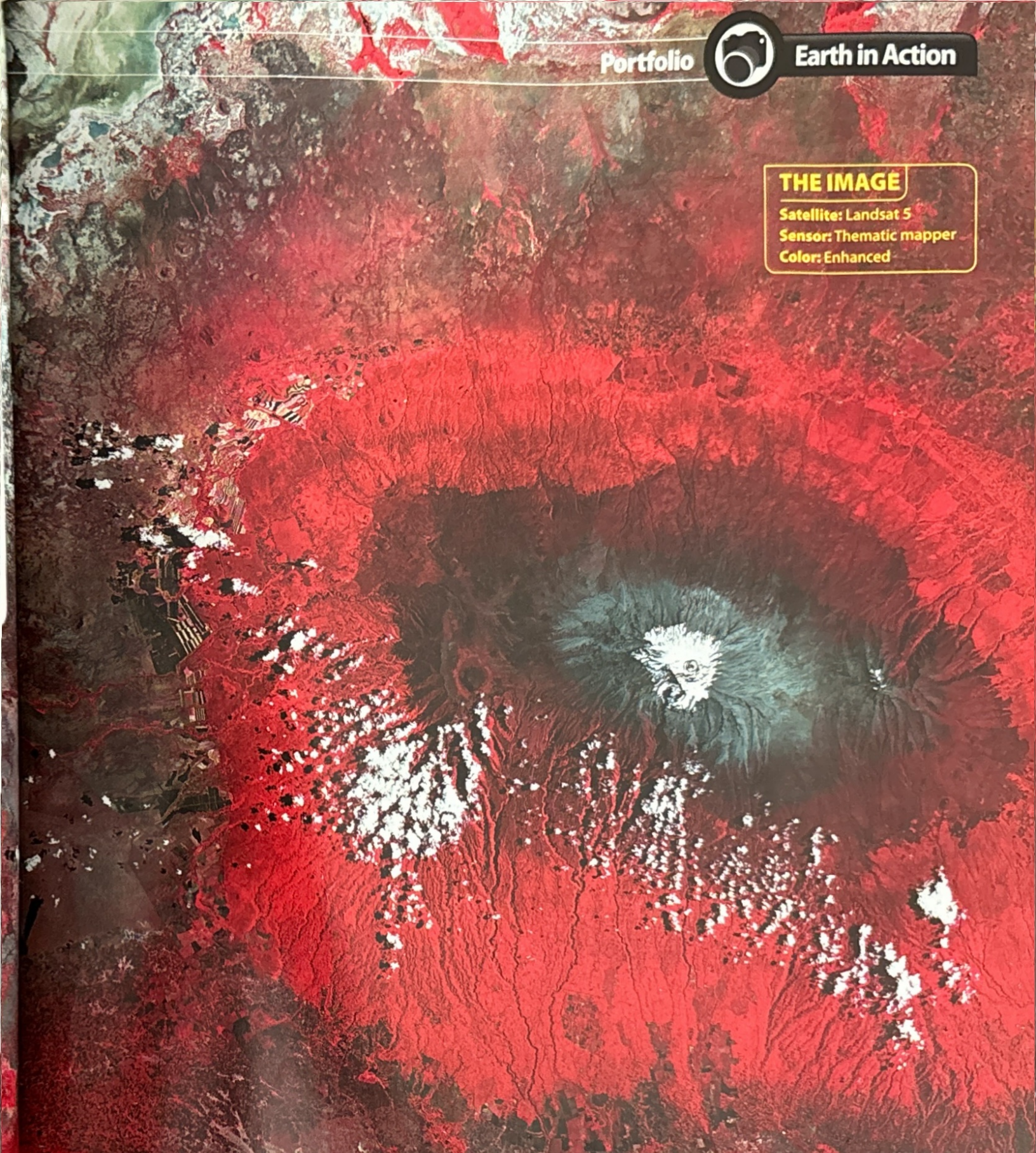
At 16,024 feet, New Guinea's Puncak Jaya—known by mountain climbers as the Carstensz Pyramid—is the world's tallest mountain found on an island [its peak is in the small circle]. Intensive mining has caused great environmental damage to the unique area. The hole to the west of the peak [large circle] marks what used to be a second towering mountain but is now Grasberg, the world's richest copper and gold mine. The removal of 125,000 tons of ore has replaced the peak with a 1,300-foot crater. The shrinking remnants of three rare equatorial glaciers in fast retreat are also visible [numbered].

GLACIERS FILL THE LAKES

Warm weather and waning precipitation are causing the glaciers of the Patagonia region in southern Chile to retreat. At Ultima Esperanza Fjord, the "Last Hope" in Spanish, one glacier now flows into a lake, creating a stunning scene. Meltwater from the glacier's foot runs down into a valley, forming a lake that glows emerald-green from the minerals in the rock. Humid air blowing in toward the mountains cools when it reaches a certain altitude, creating clouds over the ice.

THE IMAGE

Satellite: International Space Station
Sensor: Optical camera
Color: Natural



THE IMAGE

Satellite: Landsat 5
Sensor: Thematic mapper
Color: Enhanced

A LANDSCAPE CHANGES UPHILL

Africa's tallest peak, the volcano Kilimanjaro, rises 15,100 feet from the surrounding plains, with a summit 19,340 feet above sea level. The climate changes on the way up and, along with it, the landscapes. The red areas of the image represent abundant vegetation growing near the base, while grassy moorlands are found higher up in the wine-colored region. The southern side [in the lower area of the photo] has the lushest growth; prevailing winds come from the southeast and dump life-giving precipitation on this slope before passing over the mountain. The green band near the peak is a rocky, debris-filled glacial zone topped off by a snowy summit.

THE IMAGE

Satellite: Terra
Sensor: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Color: Enhanced

ICE HIDES A MOUNTAIN RANGE

The highest peaks of Antarctica's Ellsworth Mountains, led by the 16,066-foot Vinson Massif [in circle], poke through a blanket of ice created by the confluence of many small glaciers that make up the famed Ronne Ice Shelf. Constant frigid temperatures prevent the ice from ever melting. Instead, the glaciers continue all the way to the sea, their white surfaces broken only where the ice has pressed down over a sharp ridge. There, the ice splits and creates crevasses averaging 150 feet deep.

MOUNTAINS MAKE WAY FOR A GLACIER

Only a satellite image can capture the entirety of the gigantic Malaspina glacier, which spans 1,500 square miles on the southeastern Alaskan coast. The glacier can be seen here [in circle] flowing toward the coast through a pass between mountains. It carries large amounts of rocks and gravel with it. At its edges, where the ice melts, this material is deposited, creating a landscape called a moraine [brown area]. Summer vegetation fills a swath of land between the glacier and the Gulf of Alaska. This landscape typifies the more widespread glacial action during the last ice age.

THE IMAGE

Satellite: Landsat 5
Sensor: Thematic mapper
Color: Natural

A VOLCANO ERUPTS

Sicily's Mount Etna is one of the world's most active volcanoes. Its latest eruption began in 2002 and spewed ash and lava for months. The ash formed a cloud 300 miles long that drifted east and was visible from space. Etna, which has been active for more than 2.5 million years, is a composite volcano with a tall main cone consisting of ash, pumice and hardened lava ejected by the volcano. Unlike other similar volcanoes, Etna has more than one active center and possesses several smaller cones, which have formed on lateral fissures that extend down the mountain's sides.

THE IMAGE

Satellite: QuickBird
Sensor: Optical camera
Color: Natural

THE IMAGE

Satellite: Landsat 7
Sensor: Enhanced thematic mapper (ETM+)
Color: Natural

SNOW TOPS THE WORLD

The expansive Himalayas are home to Mount Everest [in circle]—the highest peak on Earth—which rises 29,029 feet on the border between Nepal and China. In this image of Sagarmatha National Park, the seasonal monsoon clouds are absent over the mountain range. Everest is covered by a fresh coat of snow this time of year, and the area is ready for thousands of visiting hikers. Over many years, the snow on the mountainsides compresses into ice, creating large glaciers that move down through valleys. When the ice melts, rivers form that will flow for hundreds of miles before reaching the sea.

THE IMAGE

Satellite: Ikonos
Sensor: Optical camera
Color: Natural

A ROCK WATERS A DESERT

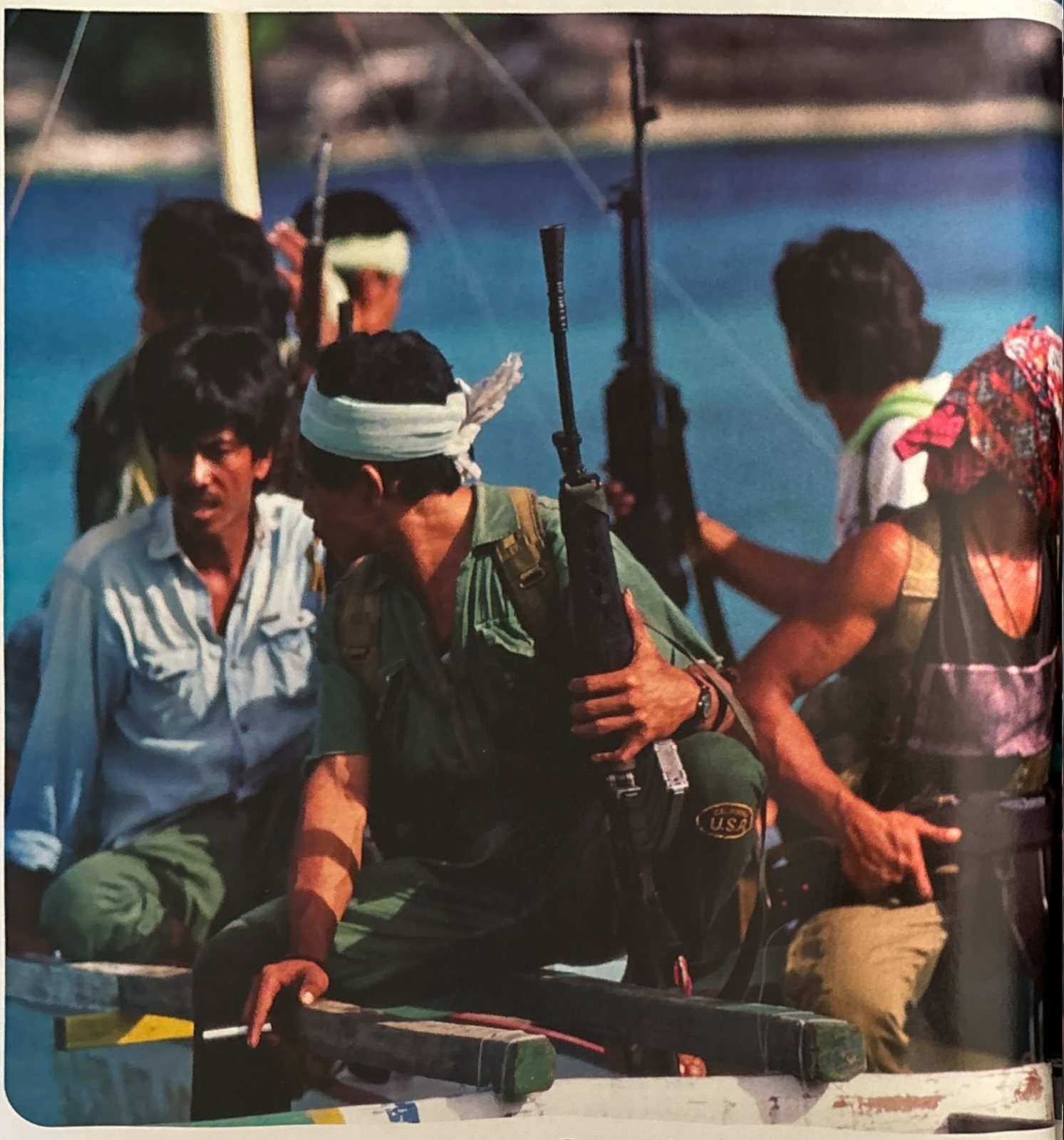
In the center of the Australian continent, Uluru, or Ayers Rock, rises 1,142 feet out of the dry plains, providing shade and water to plants and animals. The area's sparse rainfall trickles down the rock formation and drains out slowly to form little springs where plants can grow. Small amounts of oxidized iron embedded in the sandstone give Uluru its famous shifting color as the sun passes over it. At sunset, the formation appears to glow red. In 1987, the rock along with the surrounding Uluru-Kata Tjuta National Park was designated a World Heritage Site.

A COLLISION CREATED THE ANDES

The world's longest mountain range, the Andes, flanks the western coast of South America, which is colliding with the ocean floor. Because the rocks forming the continents are lighter than the oceanic crust, the Andes rise up as the floor of the Pacific Ocean slides beneath South America at a rate of about four inches a year. In this image, the colors reflect altitude. The highest mountains are white, while the black bands along the coast represent the deepening sea.

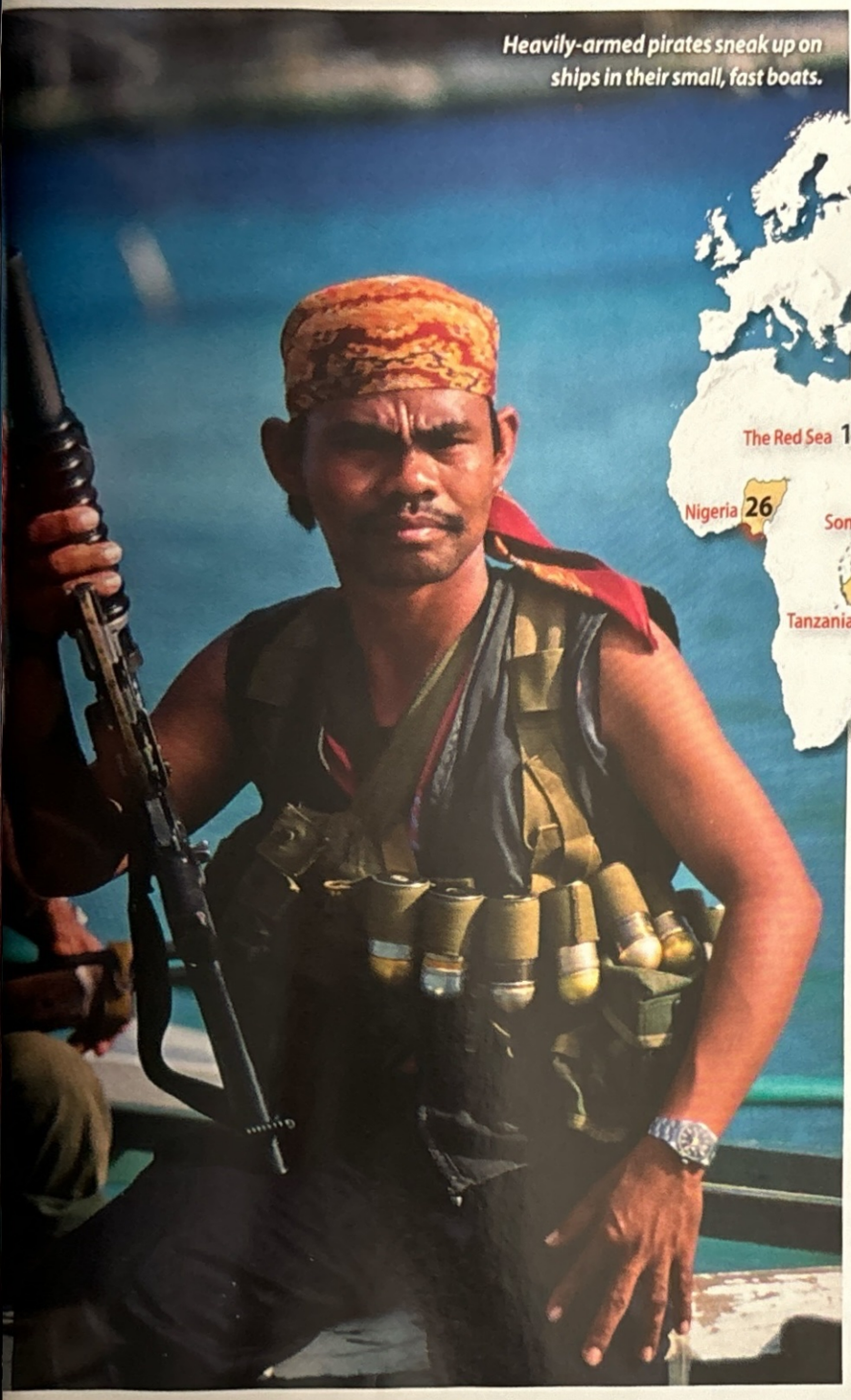
THE IMAGE

Satellite: Various
Sensor: Combined from multiple data sets
Color: Enhanced



The High-Tech Battle Against Pirates

Almost every day, pirates attack ships around the globe, plundering goods and endangering crews. But shipping companies are investing in high-tech defensive hardware so sailors and their cargo can reach port safely



Heavily-armed pirates sneak up on ships in their small, fast boats.

Almost two thirds of pirate attacks in the first nine months of last year were concentrated in just six coastal regions of the world.

The Most Dangerous Waters

According to the latest report from the International Maritime Bureau, 198 vessels were attacked in the first nine months of 2007. Almost two thirds of these incidents were concentrated in just six regions of the world, the most dangerous being the waters around Indonesia, where pirates attacked 37 times. Assaults became more common last year near Nigeria and Somalia, which tied for second place, with 26 occurrences each. (Pirate attacks more than doubled in the waters near Somalia; in 2006, the country's coasts saw only 10 episodes.)

Other regions have seen improvement. Prior to 2007, the Strait of Malacca, between Malaysia and Sumatra, was among the world's most pirate-infested waters. But patrols in the region brought pirate ambushes down to just two in the first three quarters of 2007.

After nearly three nerve-wracking months, five Danish sailors were freed last August, ending an ordeal that began when pirates captured the freighter *Danica White* off the Somalian coast. It wasn't until the shipping line reportedly agreed to pay more than a million dollars in ransom that the crew was released. Although the sailors were unharmed, they had feared for their lives every day.

If the notion of high-seas hijackings conjures images from *Pirates of the Caribbean*, it's time to update your thinking. In real life, piracy is far from any Disney movie. Worldwide, approximately 250 ships are attacked every year, according to the International Maritime Bureau (IMB), a division of the International Chamber of Commerce. The waters off the coasts of poor nations and failed states, which have effectively lost control over their territories and borders, are especially ravaged. For the past decade, the seas around Indonesia have been a favorite hunting ground. The Strait of Malacca, between Indonesia and Malaysia, until recently was one of the most pirate-plagued areas in the world. In the past year, though, shipping lanes near Somalia and Nigeria

A Victim of Piracy

One of the world's best-known yachtsmen, Peter Blake of New Zealand was shot and killed by pirates at the end of an environmental expedition on the Amazon River on December 5, 2001. His boat, the *Seamaster*, was anchored near the town of Macapa, Brazil—where the Amazon meets the Atlantic—after spending three months on the river. When a team of river bandits boarded the vessel, the crew fought back. Blake grabbed a gun and wounded one of the pirates, but another shot him twice in the back. As many as 30,000 people took part in a 2001 memorial ceremony for Blake held in Auckland, New Zealand.

have become even more dangerous than it. And while the waters off Bangladesh are still some of the most dangerous in the world, better patrolling in recent years has reduced the number of attacks there considerably—down from 33 in 2006 to just 13 in the first nine months of 2007.

Pirates aren't discriminating; some will steal anything, from watches to paint to food. They've also been known to take the ship itself, repaint it, and fabricate phony papers. Off the coasts of Nigeria and Somalia, kidnapping the crew is one of the most frequently committed crimes. Shipping companies almost always pay the ransom, which can range from $200,000 to $1.8 million. Pirates fetch the highest ransoms when their captives are citizens of Western nations.

Today's pirates are professional criminals, armed with rocket-propelled grenades and machine guns. They track ships with GPS units, radar and radio direction finding—the triangulation of a radio signal's location using two or more directional antennas. Some shipping companies also suspect that pirates may bribe port authorities and shipping-line employees for inside information on ships' cargoes, positions and planned routes, although there are no confirmed incidents on record.

But just as pirates use advanced technology, many of the ships that sail in dangerous waters are adopting high-tech devices that can ward off even the best-equipped criminals.

A New Way to Yell "Mayday"

Communication and identification are the first lines of defense. The French satellite company CLS offers ShipLoc, a system that consists of a satellite transmitter, GPS receiver and small antenna, all packed into a watertight container. The unit, which crew members hide aboard the ship as a preventative measure, transmits a signal 24 hours a day, sending the ship's speed, course and position to a central office. If pirates attack, the crew can trigger a silent alarm that alerts CLS, which then notifies the International Maritime Organization (IMO), a United Nations special agency. The IMO, in turn, notifies authorities near the ship's location. Meanwhile, ShipLoc continues to transmit a signal, making the hijacked vessel easy to track.

Ships equipped with another tracking tool, the Automatic Identification System (AIS), use a radio transmitter that broadcasts to other vessels, the U.S. Coast Guard and port authorities, providing information on the ship's speed, position, course and cargo. (In poor visibility, the system can also be used to locate nearby boats to avoid collisions.) Ships broadcasting the signal are generally deemed friendly, but it's an imperfect system. AIS is required in American waters only for passenger ships over 150 tons and other vessels that displace more than 300 tons; recreational watercraft, fishing boats and ships that never sail in American waters are unlikely to use it. And, AIS is a double-edged sword: Pirates could use the information it broadcasts to find a good target.

Visual surveillance by an unmanned aircraft is one of the most promising new tactics. UAS, Inc., in Las Vegas is developing a line of planes and blimps that can watch over ships as they sail through pirate-plagued waters, or permanently patrol areas where pirates work. The first on the market is the Inventus, which is equipped with cameras that continuously send images to a land-based control center that can quickly dispatch patrol boats if a suspicious or unauthorized vessel is discovered. It's also armed with remote-controlled air-to-surface missiles, allowing it to help ward off attackers before patrol boats arrive.

This year, floating robots will also join the war on piracy. Leading the way is Palm Beach, Florida–based Marine Robotic Vessels International. In 2003, the company first produced a prototype of a remote-controlled patrol boat called the Ghost Guard. It's now been replaced with a commercial vehicle, the Interceptor. Using microphones, loudspeakers and cameras mounted on the robot craft, remote operators can question unknown ships and prepare for an attack if there's cause for suspicion. If a robot boat's cameras witness a pirate attack, its operators can notify authorities from a distance. And if an attack can't be stopped, the boat 'bot can track the pirates to land.

Fighting Back

Observation, tracking and rescue go only so far, though. The world's oceans cover

140 million square miles, and help can be a long time coming. Although fast ships can try to outmaneuver pirates, heavily laden freighters and liners don't have that option. Their crews must keep attackers at bay through other means.

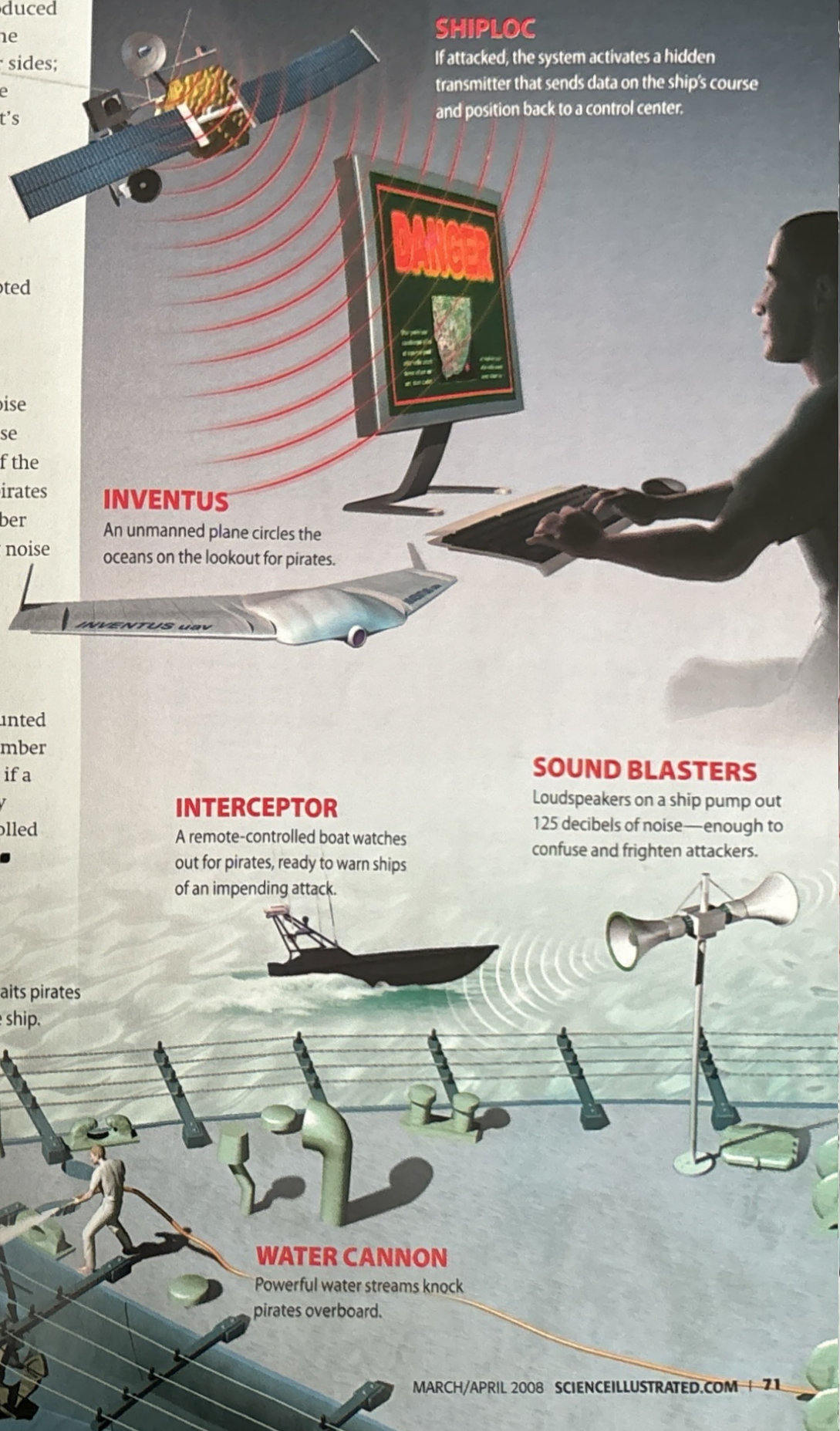
One of the newest active defenses is Secure-Ship, an electrified fence produced by the Dutch firm Secure-Marine. The fence is mounted on a ship's rails or sides; if pirates try to climb aboard, they're welcomed with a 9,000-volt shock. It's not lethal, but it's a strong enough jolt to toss away attackers. To date, about 30 ships have been fitted with Secure-Ship. And according to Secure-Marine, the device has already thwarted at least one attempted boarding off the shores of Vietnam.

Sound can also be an effective defense. "Acoustic barriers" made of powerful speakers that pump out noise at more than 125 decibels can confuse and frighten attackers, as the crew of the *Seabourn Spirit* can attest. Somalian pirates attacking the luxury liner in November 2005 were repelled by the deafening noise from the ship's acoustic defense as they prepared to board.

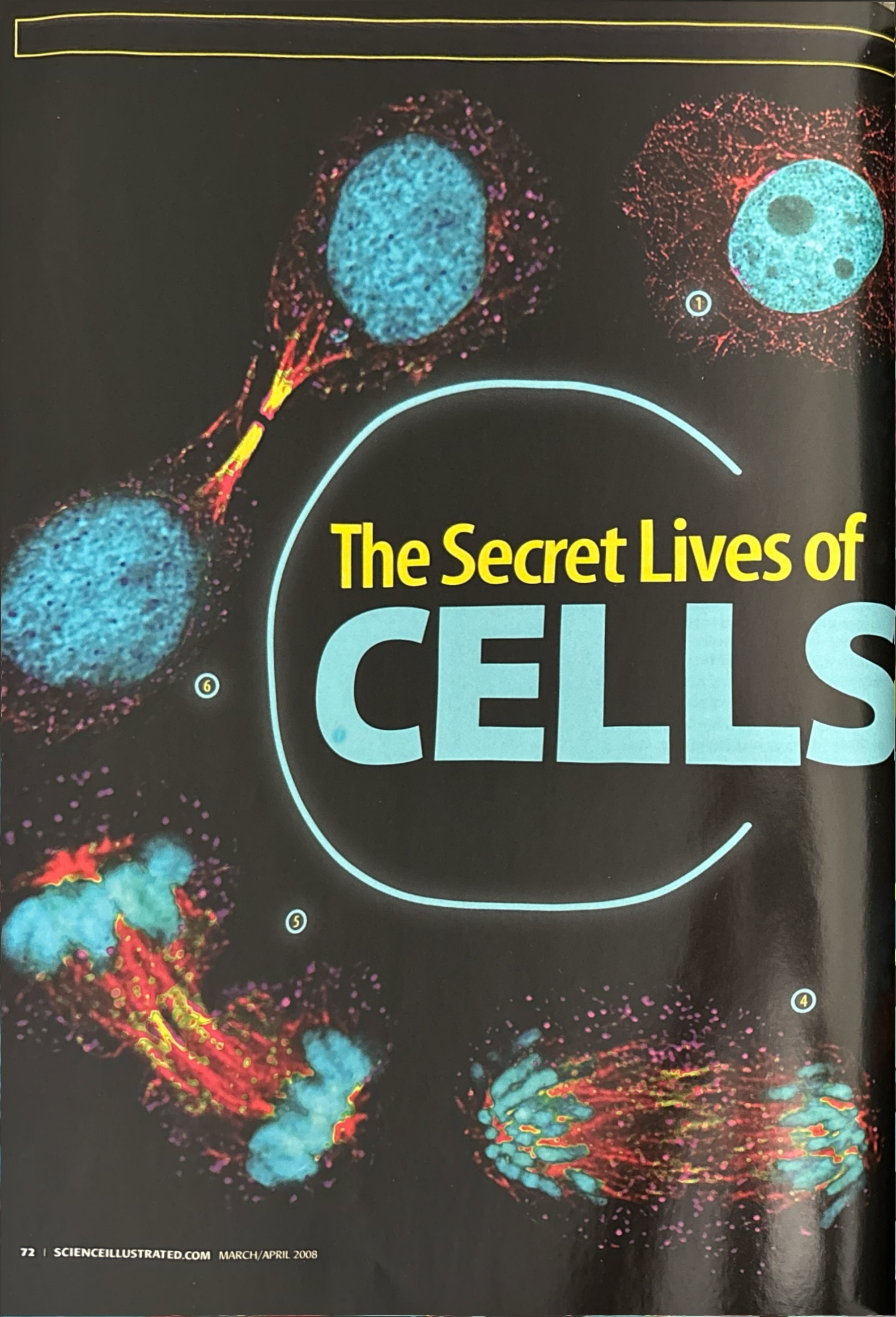
When all else fails, some crews revert to a time-honored, low-tech method of defense: blasting pirates overboard with water from ship-mounted firehoses. On small boats, a crew member mans the hose during an attack. But if a pirate assaults a large tanker, he may meet his fate against a remote-controlled cannon with up to a 300-foot range. ■

Shock and Sounds Keep the Wolves at Bay

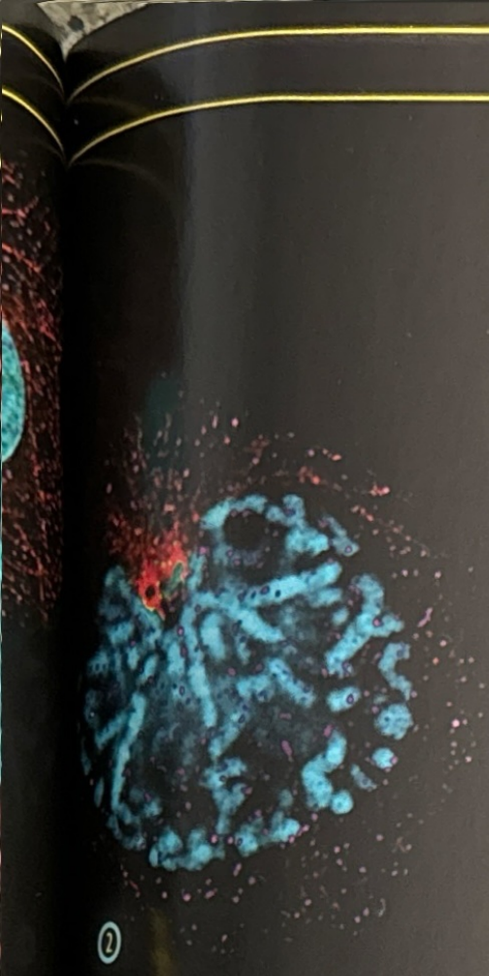
If shippers want to evade pirates, they need to arm themselves for combat. The available arsenal features everything from water cannons to electric fences to high-tech scout boats and drones.


SHIPLOC
If attacked, the system activates a hidden transmitter that sends data on the ship's course and position back to a control center.
DANGER
INVENTUS
An unmanned plane circles the oceans on the lookout for pirates.
INVENTUS uav
SOUND BLASTERS
Loudspeakers on a ship pump out 125 decibels of noise—enough to confuse and frighten attackers.
INTERCEPTOR
A remote-controlled boat watches out for pirates, ready to warn ships of an impending attack.
SECURE-SHIP
A painful 9,000-volt shock awaits pirates if they try to climb aboard the ship.
WATER CANNON
Powerful water streams knock pirates overboard.

HENNING DALHOFF



The Secret Lives of CELLS



Biologists have long faced a tricky problem when it comes to studying cells: The only way to see their inner workings is to kill them. Conventional observation methods are a bit like autopsies. You start with a dead plant or animal and then peel back the layers to see what's inside. Scientists can get a general idea of what's in a tissue sample by cutting it into thin slices or liquefying it in a blender. But what if you want to see the cell in action to determine, say, how a hormone binds to a receptor to trigger a nerve signal, or to watch how a plant transports sugar from leaves down to roots? These fascinating processes, once impossible to observe, are now visible thanks to new imaging technology that lets researchers study living, breathing cells to see how life works on the microscopic level.

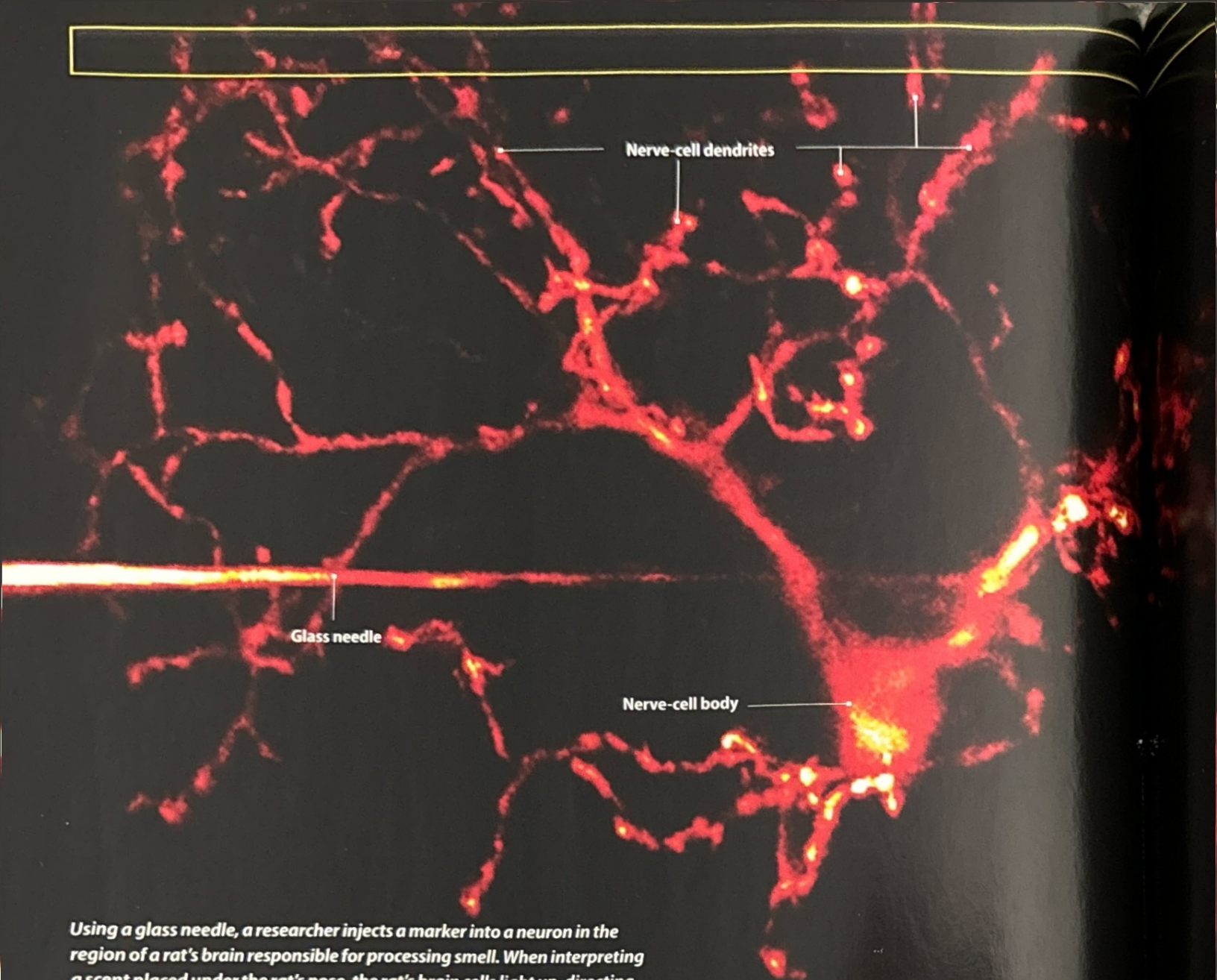
Advanced microscopes and sophisticated laboratory work have revolutionized our ability to observe the inner workings of a cell. Now scientists can see the smallest unit of life in action—without destroying it in the process

Most cells divide and replicate through the process of mitosis. Now scientists can observe the phenomenon in real time (steps 1–6). The cell's DNA is blue, and the internal skeleton—or microtubules—are red.

Glowing Jellyfish

One powerful imaging technique involves making the tiny cell components—like proteins, ribosomes and mitochondria—fluoresce beneath a microscope. To do this, researchers tag the component with a chemical that emits a bright glow in a particular color.

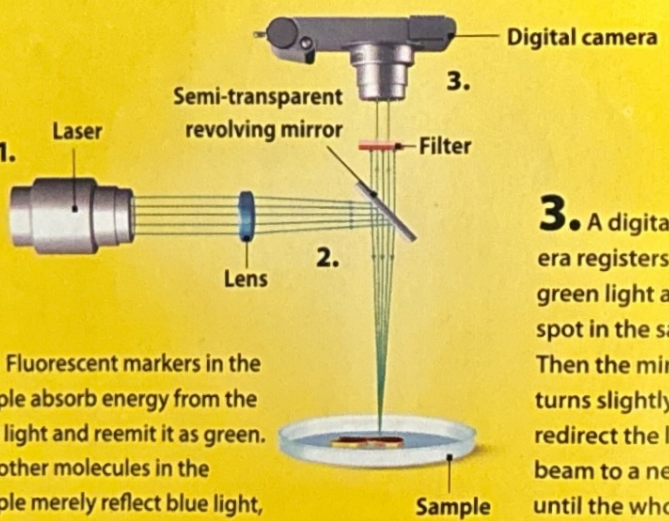
A critical breakthrough in this area came in 1994, when biologist Martin Chalfie, of Columbia University extracted a molecule called green fluorescent protein, or GFP, from a jellyfish. Using a technique called gene splicing, he inserted it into the DNA of two species, *E. coli* bacteria and nematode worms, allowing him to see the transformed cells. When GFP is illuminated with blue light, it glows bright green, and this is precisely what happened to the bacteria and nematodes. Researchers refined Chalfie's gene-splicing techniques and began binding GFP to even smaller cell components. A single neurotransmitter in the brain—or a



Using a glass needle, a researcher injects a marker into a neuron in the region of a rat's brain responsible for processing smell. When interpreting a scent placed under the rat's nose, the rat's brain cells light up, directing researchers to the cells specialized in interpreting the odor.

Inside a High-Tech Microscope

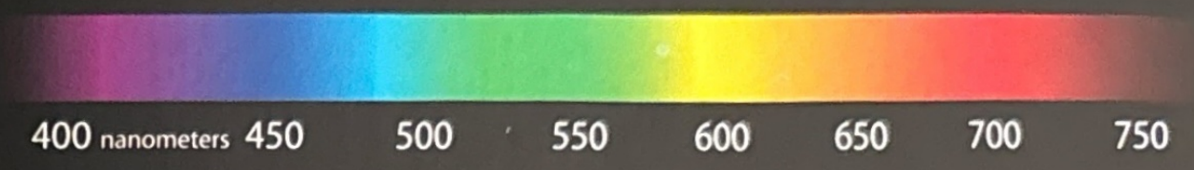
A confocal scanning laser microscope views samples section-by-section to create a series of images. A computer turns them into a 3-D representation of the entire object.



1. A laser emits blue light that's focused using lenses and an adjustable mirror. It passes through a pinhole and hits a tiny area on the sample. This eliminiates blur.

2. Fluorescent markers in the sample absorb energy from the blue light and reemit it as green. The other molecules in the sample merely reflect blue light, which is filtered out.

3. A digital camera registers the green light as a tiny spot in the sample. Then the mirror turns slightly, to redirect the laser beam to a new spot until the whole sample is scanned.



Markers in Every Color of the Rainbow

The visible light spectrum encompasses wavelengths ranging from 400 nanometers [violet] to 750 nanometers [red]. The longer the wavelength, the less energy the light contains. A fluorescent marker that absorbs blue light, for example, reemits it at a slightly lower energy level as green light.

photoreceptor in the retina, or a protein in a cancer cell—could be made to fluoresce.

GFP has so far proved invaluable in studying disease. Take, for instance, malaria. Scientists studied the possibility of producing sterile male mosquitoes to release into the wild, where they would be unable to produce more malaria-carrying insects. But they struggled to distinguish the males from the fertile females, which, if released where they could continue to produce offspring, would have worsened the epidemic. Genetic manipulation solved the problem. In 2005, researchers at Imperial College London developed a modified mosquito, in which the fluorescent GFP molecule was bound to a protein found only in the male mosquito's sex organs. The scientists produced mosquitoes in large numbers and then illuminated the larvae with blue light. The males had two bright spots of green near their tails, but the females didn't glow at all. Using a special device that detected the green spots, scientists could quickly sort the larval mosquitos by sex and release only the males into the wild.

A Splash of Color

Researchers have since moved beyond the green glow of the jellyfish protein and have found other proteins to use that fluoresce in different colors. This makes it possible to study several cell components at the same time. They have also found ways to bind the markers more firmly to molecules without disturbing their natural functions in the cell. How a protein functions depends almost entirely on its shape, like a key that fits into a lock. You can't change the long, thin end of a key without destroying its functionality—but you can reshape the big, round part that you hold in your hand. In much the same way, scientists attach markers to proteins at specific positions that aren't critical to their

New markers make it possible to study several cell components at the same time.

function, so their ability to act within the cell isn't negatively affected.

These biomarkers serve a host of different tasks, but they all share one thing in common: You need a fluorescence microscope to see them. Like a standard microscope, these specialized scopes have a light source built into them. But the light shines at a precise wavelength to cause a particular marker to fluoresce. Here's how: When the light hits the marker, the marker absorbs particles of light, called photons, and is boosted to a higher energy state. To return to its original state, the marker emits a detectable bit of light, causing a brief glow, and rids itself of the surplus energy. Because this second photon is slightly lower in energy than the first, it has a longer wavelength—and thus a different color—than the original light. When GFP, for instance, is activated by blue-purple light with a peak wavelength of 395 nanometers, it emits green light with a wavelength of 509 nanometers.

Researchers are using GFP and its variants more and more frequently, but there are many other fluorescing markers that are not proteins. One of the most popular is a blue-glowing synthetic dye molecule called DAPI. Under normal conditions, this substance is only weakly fluorescent. ▶

THE DETECTIVE

Countering the Atlantis Hypothesis

Writers Ivar Zapp and George Erickson have argued that, because the stone spheres were perfectly round, they must have been 12,000-year-old relics from a technologically advanced culture: Atlantis. In 2001, **John W. Hoopes**, an archaeologist and anthropologist at the University of Kansas, debunked the writers' sensationalist claims by citing previous research on their weight and measurements. They are not nearly as perfectly round as once thought.

This long-forgotten sphere was abandoned roadside.

One of the few remaining spheres that have been left in place.

Among Costa Rica's more prosperous citizens, it became stylish to place a Bola Grande in the front yard. Other spheres ended up in parks or in front of public buildings. And if they were in the way when farmers needed to clear a field, the spheres were moved or blown up. After rumors of gold hidden inside began to circulate, some people took to smashing them in hopes of an easy payday. Of the approximately 200 larger spheres originally discovered, fewer than 10 remain in their original locations.

The creators left no written records of their culture or ways of life, nor is there any oral tradition about Las Bolas Grandes. And because carbon-14 dating can be applied only to organic materials, researchers had to rely on archaeological contexts and other associated artifacts to determine that the spheres date from A.D. 400 to 1500.

To the naked eye, Las Bolas Grandes appear to be perfectly spherical. This supposed precision, in particular, has inspired fanciful theories on their origin, including a connection to the mythical city of Atlantis [see "The Detective," above]. Individual spheres' diameters have been measured at several places and, according to lore, these measurements vary by just millionths of an inch. In reality, some are off by more than a few inches.

Shaped by Nature?

Most of the spheres are made of granodiorite—a hard rock, similar to granite, that is found in the Talamanca Mountains of southern Costa Rica—and gabbro, which is similar to basalt but is less homogenous. A few are made of coquina, a hard variety of limestone. A possible sphere-manufacturing workshop is thought to have existed in the Diquís Delta in the southern area of the Pacific coast, but no historical record exists.

Wild theories on the spheres origin abound, ranging from space projectiles to cast-offs from a volcano. Archaeologists have been more reserved in their theories. Some believe that stones were rolled using wooden beams or polished where they were found. Others think they were shaped by the rivers and further chipped and polished by hand using chisels, hammers and

abrasive materials. Since the culture valued labor highly, "the repetitive action was thought to increase the spheres' value," speculates John W. Hoopes, an anthropology professor at the University of Kansas.

Archaeologist Ifigenia Quintanilla of the University of Barcelona believes the spheres were shaped using a fire-and-water method. Masons could have heated a raw boulder with fire before dousing it with cold water. The temperature difference would have caused large flakes to pop off, creating a rounded surface. Then, using stone tools, craftsmen could have further refined the shape by polishing the surface.

Regardless of technique, making the stone spheres would have been an extremely labor-intensive process. So why did the creators go to the trouble?

Bringing the Heavens to Earth

Because many of the spheres were set atop small mounds, some researchers suspected they were used in funeral ceremonies as a way to illustrate, along with offerings of gold and ceramics, the social status of prominent individuals. But no human remains have ever been found near the stone spheres' original locations.

A better guess is that they had some kind of astronomical function. Archaeologists described how the spheres were laid out in groups, often in triangular or square arrays or in long rows oriented to the north, south or specific spots on the horizon that may have marked the location of the rising or setting sun at particular times of the year. The stones may have had a religious meaning for the pre-Columbian peoples living in the area at the time, who could have used the spheres to represent the heavens on Earth. The spheres' various sizes might even have corresponded to various constellations in the sky.

New spheres were found in the Diquís Delta just last year, renewing interest in the mystery. If Francisco Corrales, the director of the National Museum of Costa Rica, is successful, those stones currently serving as lawn ornaments will soon serve a much better purpose: as an interactive tourist attraction in the delta. ■

THE BEST ANSWERS YET

- **Archaeological context and artifacts suggest that the stones were made between A.D. 400 to 1500 by pre-Columbian peoples.**
- **Granodiorite, gabbro and coquina stones can take on round shapes when alternating applications of heat and cold are used to flake off chips.**
- **The stones may have been used to represent the constellations in the night sky, but no hard evidence to support this theory has yet been found.**

Not Quite a Heavenly Body

The stone sphere shown here is one of the few that are decorated. Now located in the National Museum in San José, it sports a design that is widely believed to resemble the stars in Pegasus, Andromeda and other surrounding constellations. One spiral on the sphere is thought to correspond to the M31 galaxy. But according to archaeologist Ifigenia Quintanilla, the perceived astronomical pattern resembles those seen on many naturally textured rocks. The sphere, therefore, raises more questions than it answers.

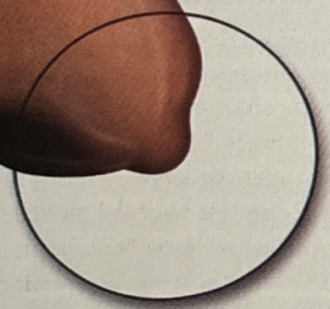
The design on this stone ball may represent the stars in the Pegasus and Andromeda constellations and the M31 galaxy.

How to

The animal kingdom boasts several species that can regenerate lost body parts. Now, thanks to an unexpected discovery in mice, limb regeneration could be on the horizon for humans

Cells Become Body-Part Factories

Limb and organ regeneration may be a reality within the next decade. Here's how it could happen:



STEP 1: Doctors prevent skin cells from forming scar tissue over a wound. They then induce the cells to return to their embryonic, or stem-cell, stage.

STEP 2: The stem cells develop into specialized cells, such as muscle, bone and fat, and begin dividing. Eventually, an arm starts growing out of the stump.

STEP 3: Growth is rapid and continues until the new arm is the same length as the existing one. The regenerated limb ages normally along with the rest of the body.

Regrow a Limb

Consider the salamander. When mishap or misadventure costs the amphibian a foot, a leg or a length of tail, it doesn't hobble along for the rest of its life making do with its remaining appendages—it simply grows a new limb. Salamanders aren't alone in their ability to regenerate body parts. Zebra fish, for instance, can replace not only lost fins and scales but also their spinal cord and parts of their heart. A flatworm can be cut into more than 250 pieces, and each one will grow into a complete animal. Until recently, though, most scientists believed that it was impossible for mammals to achieve such a profound act of regeneration.

The Discovery

That changed in 1998. Ellen Heber-Katz, a professor of immunology and oncogenesis (the study of tumor formation) at the Wistar Institute in Philadelphia, was studying a breed of mice called MRL that has an abnormal immune system. Her lab assistant had punched a large hole in the ear of each to mark the test group. When Heber-Katz examined the marked mice three weeks later, she initially assumed that there had been a mix-up. No ears were punctured. She repeated the experiment and watched as the holes closed by themselves over time. The vascular network and hair regrowth were perfectly normal.

Almost immediately, Heber-Katz shifted her research to exploring the previously unheard-of abilities of the MRL mice. The results were clear: To varying degrees, the mice could regenerate skin, cartilage, toes and heart muscle without scarring, although scientists are still trying to piece together why.

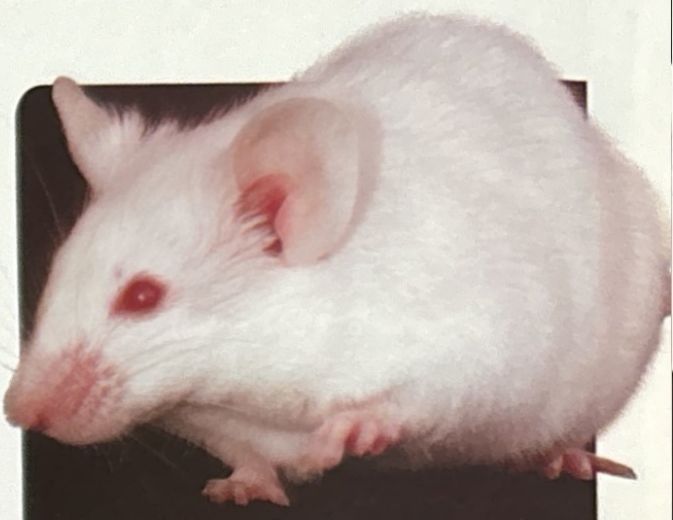
Lost in Evolution

Experts in the field believe it's likely that all animals possess the biological machinery needed for regeneration. All embryos, for example, heal wounds well into gestation. Experiments done with animal embryos have shown that the ability to regenerate limbs is found early in development and gradually diminishes until disappearing before birth. So if regeneration is a fundamental characteristic found in most organisms, and not some new trick that only a few species have developed, why have we lost it?

Mark Ferguson, of the UK Centre for Tissue Engineering at the University of Manchester, has a theory. Before the advent of modern medicine, most human wounds were dirty and couldn't be cleaned or treated effectively. That meant wounds needed to close quickly—leading to a scar—to prevent harmful microorganisms and bacteria from infiltrating. But scarring and regeneration don't mix.

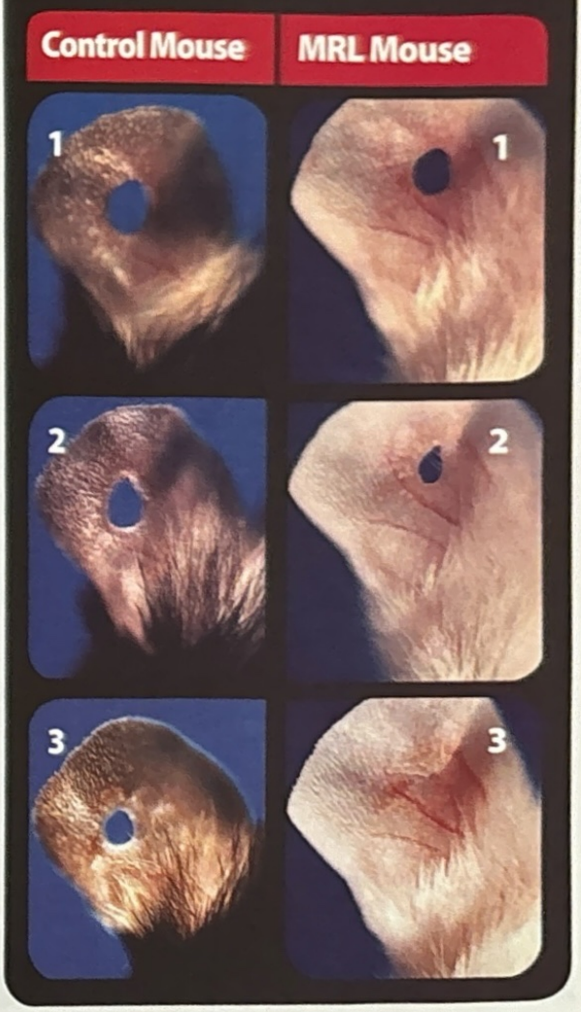
A scar is a matrix of fibrous tissue, mostly collagen, that permanently closes a wound after a scab temporarily protects it. Skin cells form a film over the injury, while white blood cells combat with dangerous microorganisms. Finally, cells called fibroblasts accumulate at the site and synthesize collagen, the protein that gives our skin its strength and flexibility.

Fibroblasts can do much more than produce collagen, though, and it's their behavior that makes the difference between the creation of a scar and the growth of a new limb. Biologist David Gardiner of the University of California at Irvine compares the role of fibroblasts with that of an orchestra director. In animals



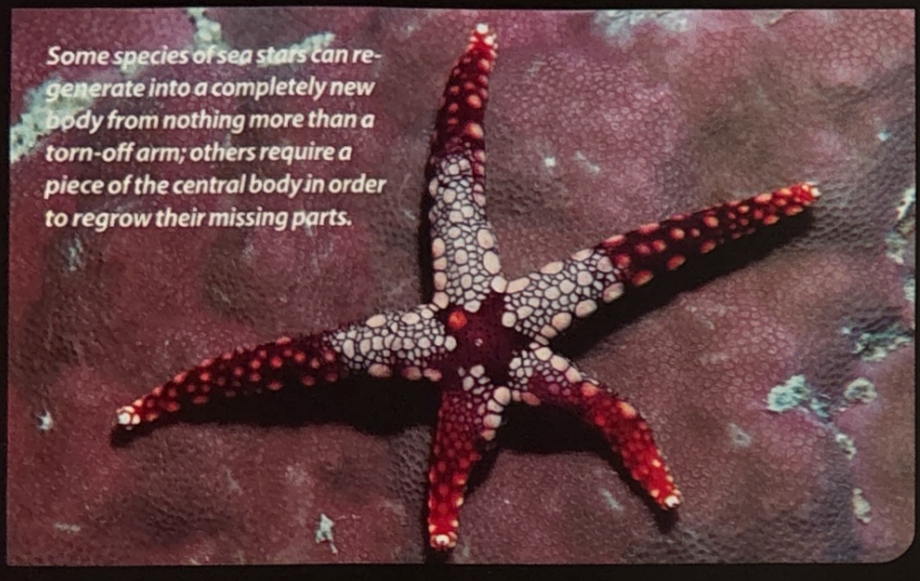
A Hole in One, or Not . . .

Mice used in experiments are often marked with a hole in one ear to allow researchers to distinguish test subjects from control animals. Surprisingly, the MRL mice were able to close the holes without forming a scar. Blood vessels and hair follicles came back like new.

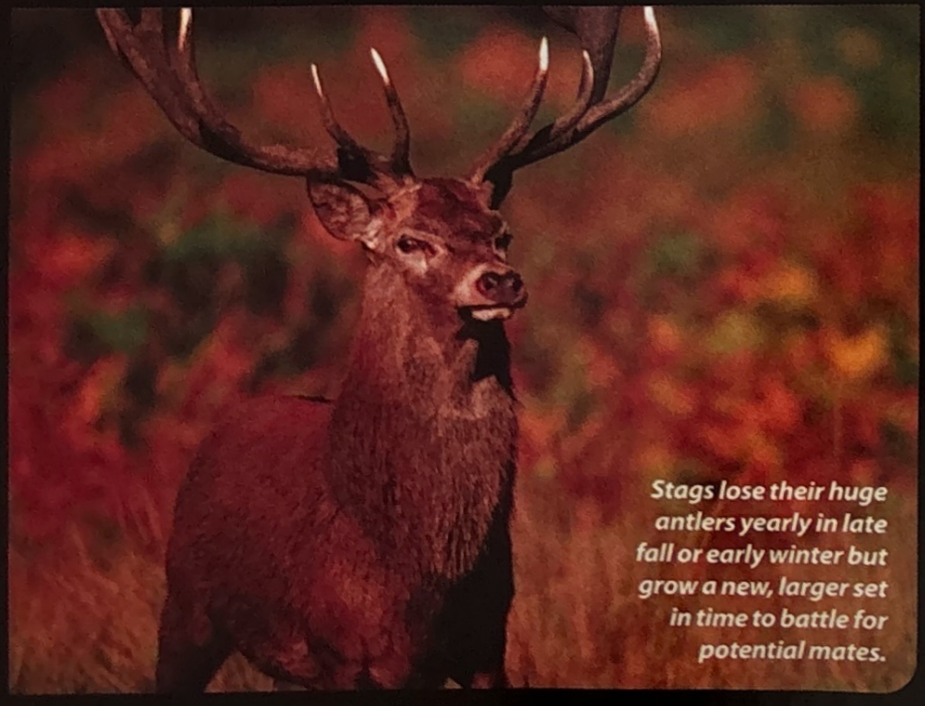


Regeneration Pros

Injured zebra fish have the ability to regrow their spinal cord, retina, fins and even up to 20 percent of their heart.



Some species of sea stars can regenerate into a completely new body from nothing more than a torn-off arm; others require a piece of the central body in order to regrow their missing parts.



Stags lose their huge antlers yearly in late fall or early winter but grow a new, larger set in time to battle for potential mates.

Spiders sometimes lose their legs when molting, but they usually grow back.

that regenerate, fibroblasts coordinate all the other cells around the wound so that they create an arm, for example, and not a finger. But in mammals, fibroblasts ignore this responsibility and instead create scar tissue at the wound site.

When a human heart is damaged from a heart attack, for instance, a scar forms instead of new, viable muscle. Every year, tens of thousands of people die from complications related to scarring in the heart. Scarring wreaks havoc elsewhere in the body as well: In the ovaries it can cause infertility, and on the cornea it can lead to blindness. The most important step toward regeneration, therefore, is to change the way the body reacts to a wound. We must find a way to stop ourselves from scarring.

Today, scientists are working toward coaxing wounds to develop a blastema—a clump of stem cells—instead of a scar. But there are major barriers in the way. It's no easy task to force the highly specialized cells in most animals back into their stem-cell stage. And once scientists can successfully force the reversion of specialized cells into stem cells, another complication may arise. Our immune systems may mistake the rapidly dividing cells in the blastema for foreign tissue and attempt to destroy them.

We Have the Power

What about the human finger, its tip cleanly sheared off in an unfortunate accident with a sharp object? In rare cases, if it's kept clean and unstitched, it can grow back as good as new—especially in children under the age of 12. So why can we perform this one small act of regeneration? Experts say it's the accomplishment of a protein called Msx1 that's active only

Learning from Lizards

Salamanders are a good model for the regeneration process researchers hope to create in humans

DAY 1: If a salamander loses a foot, the epidermal cells around the wound migrate in to close it without creating scar tissue.

DAYS 5 TO 7: The various cell types revert to stem cells in order to form a blastema, a clump of cells that will later turn into a new limb.

DAY 13: Stem cells begin to rapidly divide as they develop into specialized muscle, bone or fat cells.

DAY 31: Growth continues until the limb is just as large as the one lost. The new limb is a perfect match for the old one.

in our fingertips and seems to be more readily utilized during childhood. Msx1 works by repressing the genes that cause cells to specialize. This allows a cascade of biochemical processes, ending with the creation of the lost fingertip, to take place.

Genes determine which proteins we produce, but even though every cell in the body contains the same genes, they're not expressed everywhere. The *Msx1* gene that encodes for the Msx1 protein is permanently blocked in mammals—except in the fingertips. In a 1999 experiment using mouse muscle cells, Mark Keating, at the time a professor of cell biology and medicine at Harvard Medical School, was able to "turn on" the blocked *Msx1* gene. As a result, Msx1 protein was produced, and the muscle cells reverted into stem cells that could then become bone, cartilage or fat. Other genes involved in regeneration have also been discovered, and they all have one thing in common: They make cells behave as they did during the embryo stage.

Researchers in the Restorative Injury Repair Program at Darpa, the Pentagon's experimental-technologies branch, are working to get a wounded mammal to form a blastema instead of a scar in a non-regenerating site by May. If they are successful—and are then able to replicate the process in humans—scientists could potentially repair any wound without significant side effects.

Another promising protein is TGF-Beta-3, which is active in the creation of skin during embryonic development. After we're born, the amount of the protein in our cells declines dramatically, leading to the generation of more scar tissue. A British pharmaceutical company, Renovo, has conducted trials with a TGF-Beta-3-based product called Juvista, which they injected into human skin around fresh wounds. The treated wounds healed with less visible scarring than those that were administered a placebo. It's another significant step toward a scar-free future in which limb and organ regeneration is possible.

The gap between the salamander's ability to replace complex limbs on demand and the human talent for growing new, scar-free flesh is a huge one, to be sure. But experts in regeneration and wound healing are quickly closing the gap. Ellen Heber-Katz predicts that in the next five to 10 years, we'll be able to regrow fingers consistently, as well as damaged heart valves and spinal cords. Arms and legs could come a few years later. Within the next 50 years, she believes, any part of the human body will be able to replace itself. ■

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World of Science

When Frogs Fly

Oversized webbed feet become parachutes, allowing flying frogs to glide as far as 50 feet at a time.

For some tree frogs, life high up in the rainforest requires little use of webbed feet, a feature common among their aquatic peers. But one resourceful species, Wallace's flying frog of Southeast Asia (*Rhacophorus nigropalmatus*), has adapted its webbing to an arboreal existence. Flying frogs have oversized feet with thick, fleshy toes joined by extensive webbing. When sudden branch-to-branch or even tree-to-ground movement is needed—in search of prey or in flight from a predator, say—flying frogs extend their legs and spread their toes. Their webbing acts like mini-parachutes, enabling them to glide as far as 50 feet in a single leap.

British natural historian Alfred Russel Wallace first described flying frogs in an 1869 book after a trip to the Malay Archipelago's rainforests. Other airborne amphibians have since been discovered, but at four inches long, the species that Wallace saw (and that eventually became his namesake) is among the largest flying frogs known to scientists.

Math Mystery

The First Perfect Number

6

Greek mathematician Pythagoras (ca. 580 to 500 B.C.) and his colleagues studied perfect numbers—digits whose factors add up to the number itself—which they believed possessed magic and would bring them luck. Pythagoreans were probably the first people aware of perfect numbers, the first of which is six. Its factors—whole numbers that divide it without a remainder—are one, two and three. Pythagoreans also studied the next one: 28. It wasn't until around A.D. 100, almost six centuries after Pythagoreas's death, that a Greek mathematician named Nicomachus studied the next two perfect numbers, 496 and 8,128. And it took more than 1,300 years before the fifth one emerged: 33,550,336. Today, thanks to the quick calculations of computers, we know of 44 perfect numbers, the largest of which has 19,616,714 digits.

Watch Your Tone in Thailand

Linguists refer to the Thai language as a tonal language, because the pitch and pattern of speech affect word meanings. Thais distinguish among five tones: even, low, falling, high and rising. Words spelled exactly the same can have wildly different meanings depending on their pronunciation. The word "na," for instance, can mean "thick," "face" or "rice paddy," based on whether the tone rises, falls, or stays constant. Vowel length can also change word meaning. The tonal character of Thai makes it a challenging language for some to learn.

And although there is a standard method for translating the Thai alphabet into English, not everyone follows it. That's why in tourist brochures and guidebooks for Thailand, you'll often find the same place name spelled many different ways.

Nature's Rarities: Size Matters

The world's largest mammal . . .

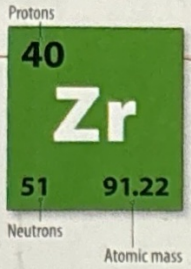
Female **blue whales** hold the record. The biggest one recorded measured 97 feet long and weighed almost 200 tons.

. . . and the world's smallest

The **bumblebee bat**, found only in Thailand's limestone caves, has a wingspan of approximately six inches. Its body is just over an inch long.

Secrets of...

Zirconium



- ***Many artificial diamonds sold since the 1970s have been made of zirconium dioxide crystals, popularly known as cubic zirconia.***
- ***Most of the commercial zirconium produced from the mineral ziron is used as coating (also called cladding) for nuclear-reactor fuel rods.***
- ***Powdered zirconium is highly combustible, making it a common ingredient in fireworks.***

Site We Love

Stellarium.org

Turn your computer into a planetarium with this free program, which gives you a realistic image of the night sky as viewed with the naked eye, binoculars or a telescope. A highlight: mythological representations of constellations superimposed onto the stars.

Icebergs on the Move

Icebergs are normally associated with the polar regions—and the vast majority are found there—but numerous shipwrecks attest to the fact that they sometimes drift to warmer waters. The best-known vessel to encounter just that fate was the *Titanic*, which rammed an iceberg about 400 miles south of Newfoundland.

The mammoth frozen bodies can be several hundred feet long, which means it takes a long time for them to melt. They sometimes make their way from the poles to warmer regions before completely melting. The southernmost position in the Northern Hemisphere that an iceberg has been seen in modern history was only about 150 miles from Bermuda.

In Europe, icebergs have been observed southwest of Ireland, and they can drift as far as Portugal's Azores Islands.

DID YOU KNOW...

THE EARTH gains about 30,000 tons in mass every year. All those extra pounds come from the cosmic dust that constantly rains down on us.

LEFT-HANDED PEOPLE make up 10 to 12 percent of the world's population.

BANANAS that we commonly eat come from a single variety that scientists say is susceptible to a fungus. More-resistant breeds are being developed.

CUMULUS CLOUDS, which are a few hundred yards long and wide, contain 25,000 to 40,000 gallons of water on average.

CLOCKWISE FROM TOP RIGHT: ISTOCK (2); K. GULDBRANDSEN/SPL/FOCI; ISTOCK; SPL/FOCI; ISTOCK; CLAUS LUNAU; COURTESY *STELLARIUM.ORG*; AL FENN/GETTY IMAGES

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As word of this discovery spread, orders from the scientific community poured in. A major Washington newspaper said they had over 50 phone calls ranging from Los Alamos to Johns Hopkins: ***"Those machines do the seemingly impossible!"*** Livermore lab: ***"We heard about this discovery over a year ago, but couldn't find you so we called the U.S. Patent Office. We want your E5 machine."*** This man has PhD's in EE, Quantum Physics and Chemistry. Edmonton Hospital M.D.: ***"I also have a PhD in Quantum Physics. You are light years ahead of everyone else. We are 1000% behind you!"***

Since we are engineers, not doctors, we keep the letters and medical reports. One of the worst cases (the report from the oncologist is on file): The man had inoperable colon cancer, tumors on the lung (lung cancer) and lesions in the liver. This man was lucky because the man's wife is in the medical field and knew about our machines. You can see on the medical chart because of the increased energy and blood flow: The moment the water got into the blood stream the CEA marker went down even before they started to treat him and every time they gave him a CAT scan the tumors became smaller until they disappeared! After breaking down the hydrogen bonds, cancer cells can't survive in a high blood oxygen environment. Also, when you open up the bond angle your blood can circulate more oxygen coming into your lungs. Oxygen is coming in from two sources! That's why the CEA marker quickly drops! This also helps emphysema!

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ALS: ***"I was told I was incurable. By the time I received your machine my fingers were frozen solid and they were spoon feeding me. Now, I am writing you this letter showing I can move my fingers!"***

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Steam	120°	Yes
Ordinary Water	104°	No
Distilled Water	101°	No

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Trivia Countdown

Earn more points by using fewer clues to answer each question.	5 points	4 points	3 points	2 points	1 point
BOTANY Name this plant:	In the U.S., the cash value of this plant's crop is second only to corn's.	It accounts for 80 percent of edible fat and oil consumption in the U.S.	Vegetarians often turn to its products for protein.	It's used to make foods such as tofu and margarine, and its fresh beans are a Japanese appetizer called edamame.	It can be processed into a brown fermented liquid called soy sauce.
CHEMISTRY Name this element:	It's an alkaline earth metal with an atomic weight of 226. On the periodic table, its atomic number is 88.	It was discovered in what is now the Czech Republic in 1898 and first extracted from pitchblende, a mineral.	Until the late 1960s, it was used to produce radioluminescent paint that made watch dials glow in the dark.	Pierre and Marie Curie and their assistant, Gustave Bémont, discovered this radioactive element.	In chemistry, the element is abbreviated Ra, and its name comes from the Latin *radius*, which means "ray."
TECHNOLOGY Name this invention:	Frank Whittle, an Englishman, is usually credited with the invention of this aircraft propulsion system.	The first test of this invention was in a German aircraft on August 27, 1939, just a week before the official start of World War II.	Most models of this engine use a gas turbine powered by internal combustion.	Since 1939, this aircraft engine has increased in power, and it has now mostly replaced old propeller engine models.	Air is sucked into the front of this engine, while hot gases are expelled out the back.
GEOGRAPHY Name this country:	The Tropic of Capricorn crosses this nation, which lies in the Southern Hemisphere.	Almost all its large cities—Darwin, Cairns, Adelaide, Brisbane, Perth—are on the coast.	The country is famous for its eucalyptus trees and its rich fauna, including koalas, dingoes and kangaroos.	Arthur Phillip, a ship captain, founded this country's Port Jackson, also called Sydney Harbour, on January 26, 1788.	It's the only country that's also a continent.
ASTRONOMY Name this planet:	It revolves around the sun every 164 years, and the average radius of its orbit is about 2.8 billion miles.	Much of what we know about this planet comes from the *Voyager 2* spacecraft, which flew by it in August 1989.	The planet is named after the Roman god of the sea. In Greek mythology, the same god is named Poseidon.	In Latin, the name of the god ended in "-us." It now ends in "-tune."	It's the eighth planet in our solar system.

HISTORY

Name this year:

February 11, South Africa: After 27 years of imprisonment, Nelson Mandela is freed. Four years later, he is elected the country's president.

April 25, U.S.: The space shuttle *Discovery* [pictured here] places the Hubble Space Telescope into orbit.

English Channel, December 1: During the construction of the Channel Tunnel linking England to France, French and British workers finally join the tunnel today.

Your guess	Points
Correct year	5
± 2 years	4
± 4 years	3
± 6 years	2
± 8 years	1

SCIENCE PHOTO LIBRARY/FOCI

Your score:

24–30 Good show, Sherlock
17–23 Not bad, Watson
9–16 Good enough, Paris
0–8 Hit the books, Homer!

Answers appear on page 94

There is a natural law that determines the results of people's behavior and defines the two choices of behavior that people can make—despite all beliefs to the contrary. Those choices are:

1. Conform to all the natural laws provided by whoever or whatever created natural laws.
2. Disobey any natural law and face failure, injury, or death.

Richard W. Wetherill
1906-1989

For several years, our one-page advertisements have appeared in national publications, explaining ***nature's behavioral law of absolute right***. The law was identified by the late Richard W. Wetherill and is described in his book *Tower of Babel* published on January 2, 1952.

Nature's behavioral law requires people to think and act in a way that is logical, appropriate, and moral. In other words, ***whoever or whatever created natural laws intends people to behave rationally and honestly rather than in ways that cause chaos and suffering for the entire human race***.

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In general, people tend to blame outside factors when they get wrong behavioral results, as comparatively few have known what causes them. Getting that few pioneers to conform to the behavioral law, despite criticism from family and friends, took nearly half a century.

They found that conforming to the law was truly liberating and dealt with situations formerly labeled "cause unknown." The thinking that causes such situations can be released when it is properly identified. Keep in mind that the organ of thought inside our heads controls bodily functions, and unless irrevocable damage has already occurred, those unknown causes can become known, and then eliminated.

The evidence is that people would often prefer to die rather than to face the fact that their conscious and unconscious wrong thinking could be ruining their lives.

People understand that they must conform to laws of physics and sometimes resist learning of the law of right behavior because its implications clearly show that the majority of people's problems and trouble are self-inflicted.

Inasmuch as it usually takes a calamity to get the public's attention for a needed behavioral change, this advertising is intended to draw attention to the calamity that has long been accepted as just a part of life.

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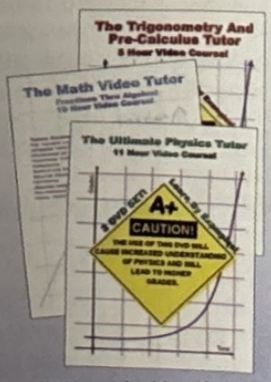

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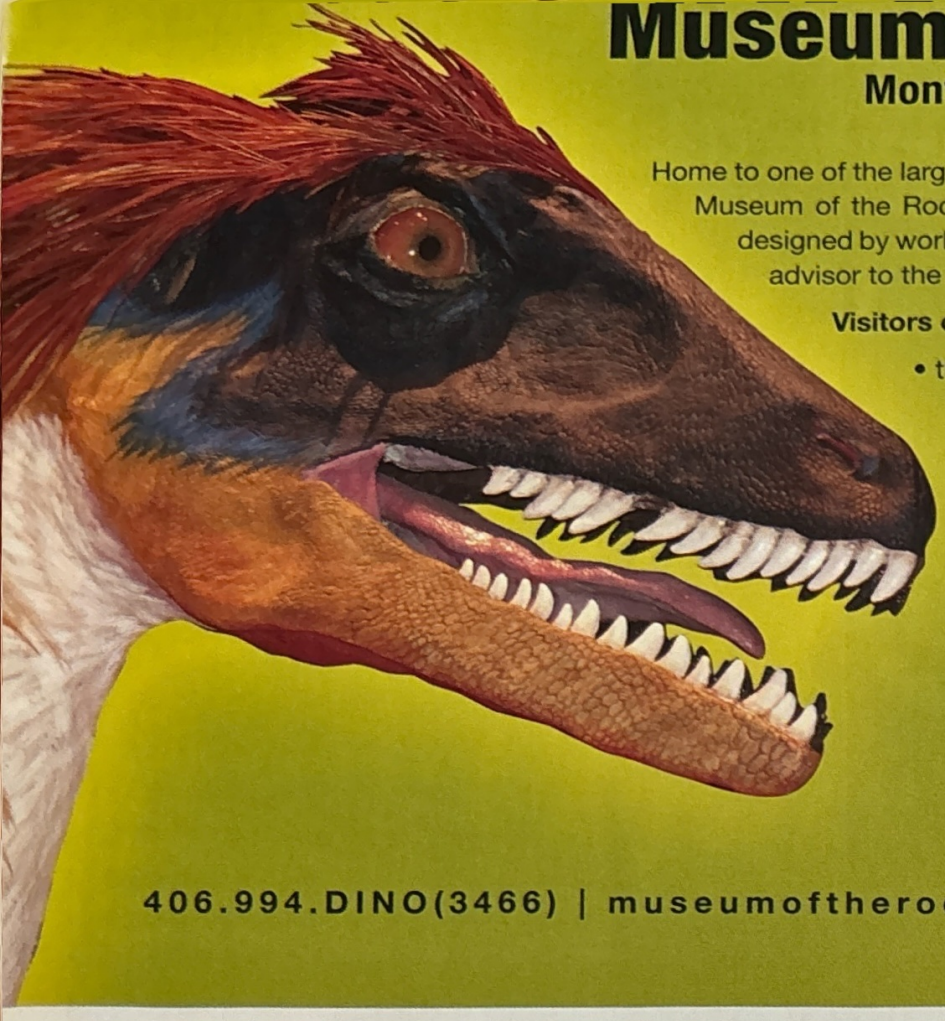

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Answer Key

TRIVIA COUNTDOWN ANSWERS:

Botany: soybeans
Chemistry: radium
Technology: jet engine
Geography: Australia
Astronomy: Neptune
History: 1990

BRAIN TRAINERS ANSWERS:

1. O and C. The letters in the diamond-shaped boxes jump forward in the alphabet by one, two, three and four letters each. The letters in the square boxes jump backward in the alphabet in the same progression.

2. 8,111.5. 4,000 + 1,100 + 0.5 = 5,100.5. And 12,000 + 1,200 + 12 = 13,212. Do the subtraction: 13,212 – 5,100.5 = 8,111.5.

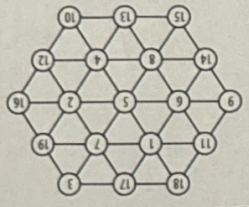
3. The number under each clock is the product of the two numbers the hands point to. The hands on the last clock point to 8 and 10, which multiply to 80.

4. Five numbers: 7, 19, 3, 17 and 2.

5. 312,211. In each pair of numbers in this series, the first describes the number of digits in the second number. So 11 means "one 1," 21 means "two 1s," and so on. The last number we see is thus "three 1s, two 2s and one 1," or 312,211.

HEADBREAKERS ANSWERS:

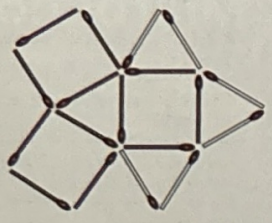
1. The sum in all the lines is 38. There are 12 possible solutions, but they are all rotations or mirror images of the correct solution shown here.



2. 27. The series is a set of numbers and exponents: 7^1, 6^2, and so on. Therefore, $3^3 = 3 \times 3 \times 3 = 27$

3. False. If this to be possible, each piece would have to contain a number of squares divisible by three. If there is n number of squares of one color, then there would have to be $2 \times n$ squares of the other color, which would make $3n$ squares in all. Therefore, the total number of squares must be divisible by three too. This is impossible: A chess-board has 64 squares—eight by eight—and 64 cannot be divided by three.

4. See diagram below.



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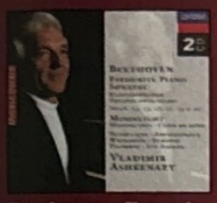

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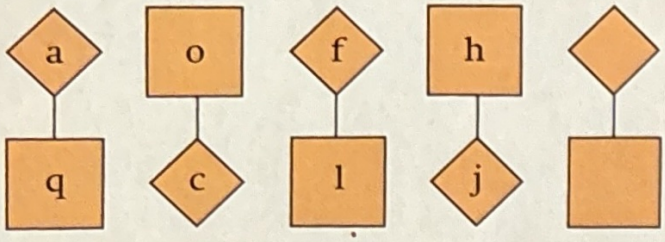
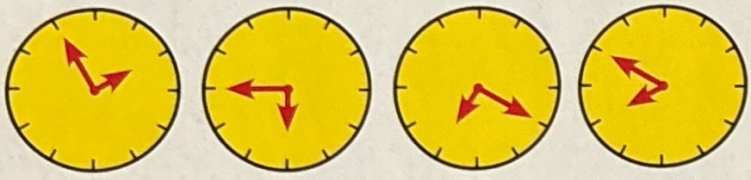
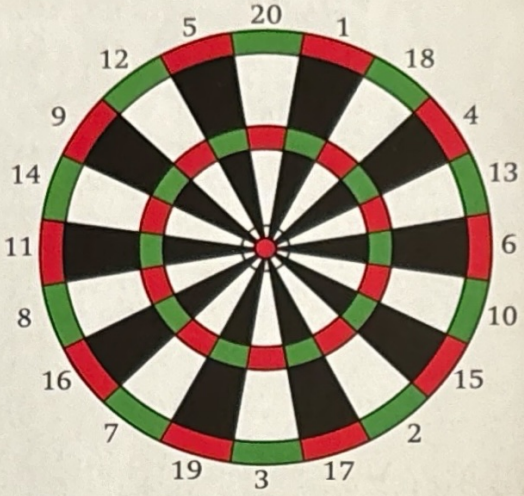


2 Do this problem in your head. Subtract the combined total of 4,000; 1,100; and one half from the combined total of 12,000; 1,200; and 12. What do you get?

3 What number goes under the last clock?



4 How many numbers are there in the longest consecutive series of prime numbers around this dartboard?

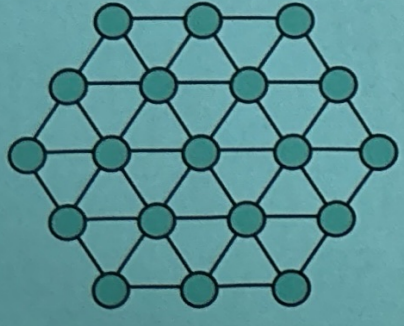


5 What number is next in the series?

1 11 21 1211 111221 ?

Headbreakers

1 Arrange the numbers 1 through 19 in the circles so that the sums of the horizontal and diagonal lines are the same.

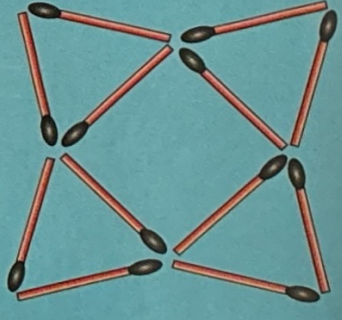


2 What number belongs in the blank space?

823543 46656 3125 256 _ 4 1

3 True or false: You can cut the board in pieces along the squares so that each piece has twice as many squares of one color as the other.

4 Twelve matchsticks form a square and four triangles. Can you move six sticks to create three squares and one triangle?



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